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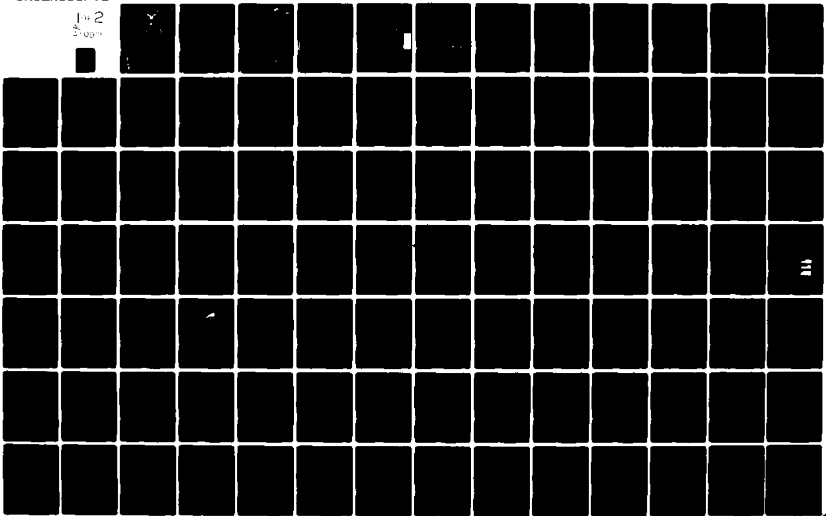

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Stephen W. Sickels, Captain, USAF

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Soviet emphasis on military investment, and on RDT&E in particular, is improving the technology base of Soviet defense systems considerably. The Soviets have a much larger arsenal of weaponry, and new technology improvements to that arsenal will give the Soviets both a qualitative and quantitative advantage in military power. In contrast, U.S. defense systems are limited in both quantity and quality by Congressional funding. Therefore, an effort must be made to achieve the highest possible quality of U.S. weapon systems within funding constraints. Pre-Planned Product Improvement (P^3I) is a strategy of system design and improvement with the potential to significantly increase system quality and at the same time decrease total life cycle cost. This thesis reviews the nature of P^3I and then examines the efforts of the Boeing Company and the F-16 Multinational Staged Improvement Program to use P^3I concepts in aircraft and missile designs. These designs are studied to understand the role of P^3I and how methods of improvement selection and planning can reduce the inherent uncertainty in long range planning. Also included is the ADPA "P^3I Summary Briefing" given to DOD, OMB, GAO, and the services and the July 6, 1981, OSD Memorandum implementing P^3I.

LSSR 59-81

PRE-PLANNED PRODUCT IMPROVEMENT (P^3I)

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirement for the

Degree of Master of Science in Systems Management

By

Stephen W. Sickels, MS
Captain, USAF

September 1981

This thesis, written by

Capt Stephen W. Sickels

has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN SYSTEMS MANAGEMENT

DATE: 30 September 1981

Ronald G. Blackledge

COMMITTEE CHAIRMAN

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Finally, I would like to thank my wife Elise, whose support made the thesis effort possible.

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CHAPTER I

INTRODUCTION

In recent years, the prevalent U.S. strategy in weapon system acquisition has been to develop and deploy defense systems with superior technology to maintain parity with less sophisticated but more numerous Soviet systems (Perry, 1981:I-7). However, U.S. defense systems are losing their superiority as the Soviets compete to upgrade their own defense technology. As depicted in Figure 1, "U.S./USSR Military Investment," the Soviets invested approximately $350 billion (1982 dollars) more than the U.S. in military RDT&E, procurement, and construction from

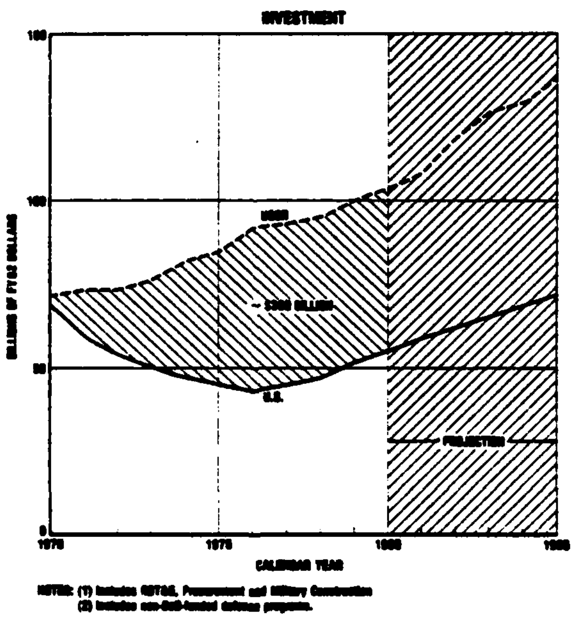

Figure 1

U.S./USSR Military Investment
(Perry, 1981:Fig.II-1)

1970 to 1980. Of these investments, Soviet RDT&E grew fastest, accelerating from $17 billion in 1970 to $36 billion in 1980. As depicted in Figure 2, "U.S./USSR Military RDT&E Expenditures," in 1970 the U.S. and Soviets invested equally in military RDT&E. Since then, the Soviets have invested approximately $90 billion more than the U.S. and today Soviet RDT&E expenditures surpass U.S. RDT&E expenditures by a margin of more than two to one.

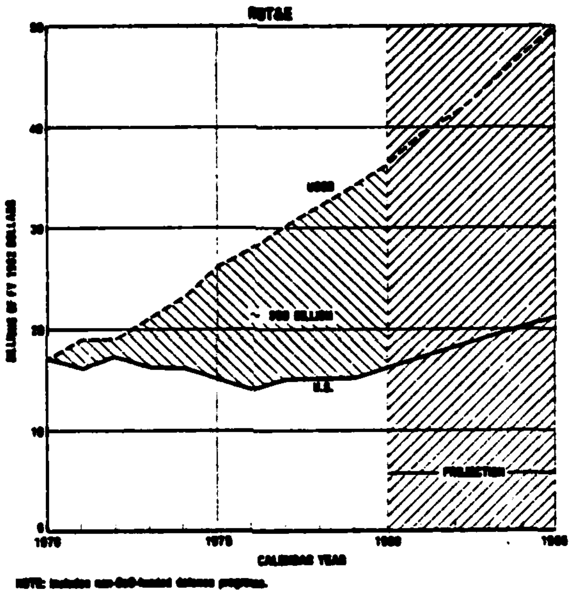

Figure 2

U.S./USSR Military RDT&E Expenditures
(Perry, 1981:Fig.II-1)

Increased RDT&E expenditures have improved Soviet defense capabilities remarkably. Today, 18 out of 30 different Soviet defense systems carry technologies that are equal or superior to technologies carried in similar U.S. defense systems (Figure 3). Such spectacular growth in Soviet technology was not unforeseen. Dr. Malcolm R. Currie, Director of Defense Research and Engineering, concluded in

DEPLOYED SYSTEM	U.S. SUPERIOR	U.S.-USSR EQUAL	USSR SUPERIOR
Strategic			
ICBM		X	
SSBN/SLBM	X —**		
Bomber	X —		
SAMs			X
Ballistic Missile Defense			X
Anti-satellite			X
Tactical			
Land Forces			
SAMs (including Naval)		X	
Tanks			— X
Artillery		X	
Infantry Combat Vehicles			X
Anti-tank Guided Missiles		X	
Attack Helicopters		X —	
Chemical Warfare			X
Theater Ballistic Missiles		X —	
Air Forces			
Fighter/Attack Aircraft	X —		
Air-to-Air Missiles	X		
PGM	X		
Air Lift	X		
Naval Forces			
SSNs			
Anti-Submarine Warfare	X —		
Sea-based Air	X —		
Surface Combatants		X	
Cruise Missile		X	
Mine Warfare			X
Amphibious Assault	X —		
C^3I			
Communications	X —		
Command and Control		X	
Electronic Countermeasure		X	
Surveillance and Reconnaissance	X —		
Early Warning	X —		

*These are comparisons of system technology level only, and are not necessarily a measure of effectiveness.

Figure 3

Relative U.S./USSR Technology Level
in Deployed Military Systems
(Perry, 1981:Table II-8)[1]

[1]Represents the consensus of DOD, CIA, DIA, and NSA (Terrell, Government organization symbols are listed in Appendix A.

his FY 1978 Statement to Congress,

> . . . without appropriate action on our part, the Soviets could achieve, on balance, a position of clearly perceived military superiority in terms of the combination of quantity and quality of their deployed military weapons at some point during the 1980s [Currie, 1977:I-2].

The U.S. recognized the importance of modernizing its defense systems, and in 1977 began a program to correct emerging deficiencies. However, the rate of U.S. inflation was greatly underestimated resulting in little real defense growth (Perry, 1981:II-2). During these same years Soviet RDT&E continued to expand. A recent assessment of Soviet RDT&E was presented to Congress in January 1981, by Dr. William J. Perry, Under Secretary of Defense Research and Engineering. Dr. Perry states,

> We can identify about 50 major Soviet systems at this point in various stages of test and evaluation. Many of these systems are quite significant . . . . It is quite clear that the Soviet R&D program has had a high priority access to funds, to trained personnel, and to scarce materials. Because of the intense and persistent Soviet committment to defense technology, it will be much more difficult to maintain our technological advantage in the future than it has been in the past [Perry, 1981:I-6].

Dr. Perry explained that the U.S. presently has an advantage in 12 of 20 critical defense technologies (Figure 4). However, the U.S. advantage in 5 of these 12 technologies is eroding towards U.S./USSR equality. The actual level of technology carried in U.S. defense systems is less favorable. Of 30 different defense systems, the U.S. has 12 that carry superior technology. However, the technology in 9 of these 12 systems is eroding towards U.S./USSR equality. Two systems of U.S./USSR technical equality are eroding towards USSR superiority. In contrast, only one Soviet system is losing its technical advantage; from superiority towards U.S./USSR equality (Figure 3). Dr. Perry states,

BASIC TECHNOLOGIES	U.S. SUPERIOR	U.S.-USSR EQUAL	USSR SUPERIOR
1. Aerodynamics/Fluid Dynamics		X	
2. Automated Control	X		
3. Chemical Explosives			X →
4. Computer	← X		
5. Directed Energy		X	
6. Electrooptical Sensor (including IR)	X →		
7. Guidance and Navigation	X →		
8. Hydro-acoustic	X →		
9. Microelectronic Materials and Integrated Circuit Manufacture	← X		
10. Non-Acoustic Submarine Detection		Cannot determine	
11. Nuclear Warhead		X	
12. Optics	X →		
13. Power Sources (Weapon)			X →
14. Production/Manufacturing	X		
15. Propulsion (Aerospace)	X →		
16. Radar Sensor		X	
17. Signal Processing	X		
18. Software	X		
19. Structural Materials		X	
20. Telecommunications	X		

The technologies selected have the potential for significantly changing the military balance in the next 10 to 20 years. The technologies are not static; they are improving or have the potential for significant improvements.

Figure 4

Relative U.S./USSR Standing in the 20 Most Important Basic Technology Areas (Perry, 1981:Table II-7)[2]

---

[2]Represents the consensus of DOD, CIA, DIA, and NSA (Terrell, 1981).

> The greater number of arrows pointing toward *Soviet superiority* . . . underscore the need to improve our exploitation of basic U.S. technology as we translate it into deployed military capability [Perry, 1981:II-34].

The Soviet acquisition strategy is also responsible for improving Soviet defense system comparison. After WWII, the Soviets began to rebuild their defense forces with simple but reliable systems that were designed for flexibility. For example, the engine of a large truck was built with a simple design for ease of mass production, yet built with flexibility to fit into a tank. Piston rods in V-6 and V-8 engines were built to be interchangeable. At times, the Soviets carried flexibility to extremes as illustrated by adapting, "manned fighter aircraft into air-to-surface missiles which then are dropped from heavy bombers [Augustine, 1981:28]." Nonetheless, the strategy of mass producing simple, reliable, but flexible defense systems has paid off. The Soviet acquisition strategy first created a base of simple weapons. Then their strategy narrowed focus to improve that base with more advanced technology. Emphasizing continuous system improvement, the Soviets now have a massive force of technologically improved weapons. The U.S. has taken a quite different approach to acquisition, buying limited quantities of state-of-the-art weapons. As the Soviets accelerate their RDT&E efforts toward more sophisticated improvements, the U.S. becomes vulnerable to the combined Soviet quantitative and qualitative advantage. Further, it is probable that the Soviets will pursue their RDT&E efforts to achieve unequivocal military superiority, not just some form of parity.

CHAPTER II

PROBLEM STATEMENT

Problem Evolution

The U.S. will continue to depend upon a relatively smaller defense force with technological superiority to compete with the increasing quantity and quality of Soviet forces. How the U.S. can maintain/regain its technological superiority in fielded weapons systems, given the threat of sophisticated Soviet system improvement, may be the most important defense challenge the U.S. will face in the 1980s. The U.S. cannot simply allocate massive amounts of money and resources to military RDT&E, as the Soviets have done. U.S. RDT&E is limited by the U.S. political milieu and the DOD acquisition strategy. Figure two shows that in the 1970s U.S. military RDT&E expenditures actually decreased, whereas Soviet RDT&E expenditures more than doubled. Since the Soviets have a centrally planned economy, their government can more easily appropriate funds for defense as they wish. U.S. defense needs must compete with social and domestic programs in an arena of political give and take. Presently, over 75% of the Federal Budget is allocated to "relatively controlled" programs, and by law these programs must be funded before defense programs (OMB, 1981:598-599). The political climate in the U.S. and its attendant push for social programs in the 1970s not only weakened U.S. standing defense forces, but also the underlying industrial base as well. With less profit in the defense industry over the last ten years, many small defense contractors have been forced out of business

and large contractors have substantially cut their percentage of military commitments. The weakened U.S. industrial base is a problem of tremendous magnitude that severely limits U.S. RDT&E efforts (DSB, 1981:xv-xvii).[3]

The DOD acquisition strategy, itself, also limits RDT&E. The U.S. has chosen to acquire a small number of technologically advanced weapon systems. With limited and highly sophisticated RDT&E facilities, the U.S. is not capable of quickly expanding RDT&E. Further, if a weapon system is already designed with a high degree of complexity, an improvement effort will usually cut across a variety of subsystem interfaces, greatly increasing the difficulty of the modification. Thus, small incremental improvements cost large sums of money - a very real limit on RDT&E. Other factors constraining rapid U.S. improvement include lengthy development time and costs of inflation. System acquisition time is lengthening; it is now averaging 17 years from mission need identification to system fielding for major systems (U.S. Congress, 1980a:328). An indication of lengthening acquisition time is the projection of lead times that the aerospace industry is currently experiencing. A 1980 Defense Science Board Study, directed by Robert H. Fuhrman, concluded that the defense industry would need at least three years lead time to boost its output to meet wartime surge requirements (DSB, 1981:13). For example, lead times for F-15, F-16, and A-10 landing gear assemblies are presently 41, 42, and 49 months respectively (DSB, 1981:32). As acquisition time has increased, so has cost. The GAO estimates that weapon system cost has increased much faster than the rate of inflation. The

[3]Lengthy sources are abbreviated in citations.

cost of an F-14 aircraft, purchased in the 1970s was more than ten times the cost of an F-86 purchased in the 1950s. Certainly new, more expensive weapons are more capable, but the DOD has not been able to purchase optimum quantities of new weapons because of increased costs (GAO, 1979: 1,2). Dr. James Wade, Assistant Secretary of Defense, estimates DOD procurement needs of $1430 billion over the next 15 years. Dr. Wade expects funding of about $1030 billion, a $400 billion shortfall (ADPA, 1980:33). The GAO came to a similar conclusion, estimating current procurement programs will cost $725 billion, "If these costs are spread over the next ten years (a conservative projection), the annual average need of $72.5 billion will be more than twice the current funding levels [GAO, 1979:3]."

This chapter began by enunciating the historic U.S. defense strategy of high technology and limited numbers. This has set the mix, number, and sophistication of weapon systems we currently have. It has been argued that simply "turning on the tap" for more weapon systems is not viable, given our present industrial posture. Faced with lengthy acquisition time, increased system costs, and limited funding, the DOD has often chosen to improve an existing system rather than develop a new system. DODD 5000.1, Major Systems Acquisitions, specifies that each new start must be evaluated against an improved version of an existing system (DODD 5000.1, 1980:2). Often system improvement is a less costly and more efficient approach to introduce new technology and improve defense capabilities. USAF aircraft modifications illustrate this fact. The F-4 was introduced into the USAF inventory in 1962, yet the aircraft will continue to be the backbone of the USAF tactical fighter force into

the mid 1990s (OO-ALC/MMS, 1980:i). To meet changing mission requirements and introduce new technology, USAF has modified the F-4 into five different mission design series with 14 different configurations. Presently there are 18 on-going safety or improvement modifications (Class IV) valued at $529.8 million and 25 on-going mission change modifications (Class V) valued at $1.4 billion (OO-ALC/MMS, 1980:2-5). The F-4 is not alone in the USAF improvement effort. The B-52 is being modified to carry the cruise missile. The KC-135 is being improved with new engines. The C-5 is being improved with strengthened wings to lengthen its operational life to the year 2000 (SA-ALC/MMS, 1980:2). The F-16 is being improved with a variety of new electronic capabilities "to maintain single pilot operability in high task/threat situations [ASD/YPPP, 1981:3-1]." General Slay, Commander AFSC, reported in 1980 that $3 billion has been spent on B-52 improvements and another $6.5 billion will be spent on B-52 avionics and cruise missile modifications (ADPA, 1980:100). Taken together, aircraft modifications make up a large portion of the USAF budget.

Even though USAF has chosen system modifications as a major method of translating new technology into deployed capability, numerous studies have concluded that the USAF modification process is not very efficient. The initial acquisition of a weapon system from the conceptual phase into production is usually the responsibility of AFSC. During production, program responsibility transfers to AFLC who assumes responsibility for production, deployment, and future modifications (AFSCP 800-3, 1976:5-6). With AFSC developing the system, and AFLC producing, deploying, and modifying the system, there often is a loss

of continuity in weapon system evolution between initial development and later modification.

AFR 57-4 identifies modifications by five classes:

> Class I—A temporary removal or installation of, or change to, equipment for a special mission or purpose.
>
> Class II--A temporary modification to support research, development or operational test and evaluation.
>
> Class III--Modifications required to insure production continuity.
>
> Class IV--Modifications to insure safety of flight, to correct a deficiency which impedes mission accomplishment, or to improve logistic support.
>
> Class V—Installation or removal of equipment changing the mission capability of the present system configuration.
>
> Updating Change--Modification requirement other than Class V, prior to program management responsibility transfer from AFSC to AFLC. (USAF, 1978:10-11).

Each class, in part, dictates who is responsible for the steps of recognizing, approving, funding, developing, and implementing the modification. ARINC Research Corporation noted that several steps are completed by different agencies and that no single acquisition manager directs the overall modification program (ARINC, 1980:viii). Lack of management direction has led to a process controlled ". . . more by politics and personalities than standards set by regulation [Klein, 1979:78]." ARINC studied Class IV and Class V modifications and concluded that the process is not only complex, but unnecessarily lengthy. Statement Of Need (SON) approval to final modification kit testing is at least three years (ARINC, 1980:2-6). Only then can one actually take a kit and modify an airplane with it. Modifying a fleet of aircraft after successful kit testing adds several more years to the process. Compounding these problems is the fact that a weapon system may undergo several modifications

simultaneously. However, each modification is acquired independently; there is no plan to integrate concurrent modifications to take advantage of common management and engineering effort, and to minimize system downtime. Since modifications are developed independently, engineers may find during system integration that concurrent modifications are incompatible with each other, as was the case with F-111 avionics improvements (Blackledge, 1981). USAF modification deficiencies became most apparent during 1979 while modifying F-4 avionics and led to command direction to improve the modification process. Since 1979, both civilian and USAF researchers have studied the modification process and conclude that a lack of long range integrative planning is the central deficiency in the process. The following is a review of findings of modification research efforts.

Directorate of Logistics Integration Project Report

In 1976, AFALD surveyed AFLC and operational MAJCOMS to identify those significant operational problems that could be traced to the acquisition process. A wide range of responses indicated that most acquisition-related problems were caused by fundamental deficiencies in the modification process (Balven, 1979:3). To further research these deficiencies, the Directorate of Logistics Integration (AQI) at AFALD, together with ASD, sponsored five research projects that focused on Class V aircraft modifications. Concurrently, a USAF/IG System Acquisition Team reviewed the modification process. Results of the IG inspection were presented to AQI for incorporation into their project report. The report, released in February 1979 after two years of research, consolidated the findings of the five AQI projects and the IG inspection and cited four funda-

mental modification process deficiencies. These deficiencies are paraphrased as:

> 1. Modification development and implementation are viewed as separate and distinct activities and managed independently.
>
> 2. There is no coherent planning for the modernization of USAF weapon systems.
>
> 3. There is no central control of the activities changing or portending change to weapon system configurations. Though the system manager is charged with configuration control, he has little involvement and authority in modification development programs.
>
> 4. There are deficiencies in the USAF corporate management of the total USAF modernization effort. Existing procedures reflect and support a fragmented approach to modification programs that result in diffused responsibilities and inadequate long range planning (Balven, 1979:7).

One could summarize these findings by stating that no single USAF modification manager has a comprehensive plan to integrate and direct aircraft modifications.

MacIsaac Air Force Institute of Technology Thesis

Capt Richard S. MacIsaac's AFIT Thesis, "A Guide for the AFLC Program Manager of Major Production Class IV and V Modifications," exposes many of the potential problems within the modification process. Capt MacIsaac cites B-52D wing fuel cell modifications as a glaring example of a deficiency in integrative modification planning.

B-52D wing fuel cells had a high failure/leak history. The down-time and expense of dismantling the wings to replace faulty fuel cells was both lengthy and very costly to USAF; therefore, fuel leaks were temporarily repaired on a continuing basis. When the B-52D was scheduled for a major wing modification, requiring that the wings be dismantled, the wing modification did not include new fuel cells. After

the wing was dismantled, defective fuel cells that could have been easily replaced were left in the wing and the wing reassembled. Capt MacIsaac notes, "There are dozens of like examples on both the B-52D and C-5A programs [MacIsaac, 1979:56]." Because each aircraft modification is acquired independently, the modification process is inefficient.

ARINC Research Corporation Report

In 1980, the Air Force Business Research Management Center contracted ARINC Research Corporation to evaluate USAF modification management. ARINC surveyed 217 development, support, user, and Air Staff Modification managers, and concluded that there are numerous planning deficiencies in the modification process. These deficiencies are paraphrased as:

> 1. Lack of weapon-system-level planning for modifications - causing integrating and space problems with increased cost and downtimes.
>
> 2. Requirements not baselined, design vacillates - causing delays and increased funding requirements.
>
> 3. Lack of long range planning in architectural concepts and design - causing suboptimum integration in design.
>
> 4. Lack of planning capability to group multiple modifications at one time - causing integration problems, maintenance inefficiency, and poor use of aircraft space (ARINC, 1980:4-3).

ARINC recommended that AFSC/AFLC develop master modification plans to identify current modifications and proposed modifications in a single source planning document for weapon system improvement (ARINC, 1980:5-5).

GAO Report To The Secretary of Defense

In 1980, the GAO evaluated USAF management effectiveness for

items used in its Class IV modification program. The evaluation included a review of DOD directives, as well as USAF policies, regulations, and procedures which govern modification kit management (GAO, 1981:2). The GAO report "Improved Management of Air Force Modification Programs Can Save Millions," criticized USAF for not screening existing USAF inventories for kit components before purchasing kits from contractors. The GAO found that in just two modification programs alone USAF could have saved $30 million by using its current inventory items rather than buying similar items from contractors at higher prices (GAO, 1981:i). The GAO recommended to the Secretary of Defense that USAF, "Amend and clarify current regulations and procedures which deal with modification programs to eliminate confusing and contradictory statements . . . [GAO, 1981:ii]."

Statements of Vice Commanders

During 1979, the Vice Commanders of TAC, AFSC, and AFLC exchanged correspondence in regard to the ". . . undesirable state of affairs concerning organization and management aspects relative to F-4 avionics modifications underway [AFSC, 1979]." The Vice Commanders' assessment of modification deficiencies are paraphrased as:

> 1. Multiple organizations being responsible for, or associated with, modifications for a particular system.
>
> 2. Separate consideration and planning for modifications out of context and without due consideration for other planned/tentative modifications, using a first in, first out basis.
>
> 3. Late involvement of AFLC systems managers.
>
> 4. Lack of visibility into the total modification picture planned for a weapon system, which could give greater insight for more efficient modification planning (AFSC, 1979:2).

As a partial solution, the Vice Commanders directed a senior officer investigative team from AFSC, ALD, ESD, TAC, and AFLC to construct guidelines for aircraft master modification plans. These plans are being implemented on a test basis for F-4 and F-16 modifications to provide long range integrative planning.

Lavoie Air War College Research Report

Col Robert P. Lavoie has had extensive experience in the USAF acquisition community, serving as a program manager at ASD, a systems staff officer at Hq AFSC, and a deputy division chief DCS/R&D at Hq USAF. In his AWC Research Report "A Faster Response to Threat Change and User Requirements," Col Lavoie describes the modification process as a reactive process, reacting to deficiencies only after they are identified as problems and then slowly responding to correct them. Col Lavoie suggests that modifications can be planned because obsolescence in technology, threat, and operational requirements can be forecasted. Based on his own acquisition experience, Col Lavoie recommends a three step weapon system improvement program. The first step exacts the most possible use from current system components by extending their life with minor modifications. The second step requires a complete retrofit of avionics and other needed systems and would occur about 12 to 15 years after initial fielding. The third step, like the first, uses minor modifications to exact the greatest use from retrofitted systems (Lavoie, 1978: 54-56). The key to Col Lavoie's improvement program is planning improvements, rather than reacting to deficiencies.

The F-4 Aircraft Structural Integrity Program (ASIP) illustrates one method that was used to plan improvements. The purpose of ASIP is

to give ". . . the system manager the visibility to predict and plan for modifications rather than observe the fleet and react to failure as has been the case in other weapons systems . . . [OO-ALC/MMS, 1980:9-3]." At the onset of ASIP, a damage tolerance assessment of each aircraft was conducted to ascertain the remaining life of critical structural areas. Critical areas were ranked from weakest to strongest to suggest an orderly plan to correct weak areas. Now, each aircraft is tracked and inspected such that weak areas can be modified before they fail (OO-ALC/MMS, 1980:9-4).

In addition to long-range planning, a modification strategy should consider the actual engineering of the aircraft. Rarely does a modification fit easily into an aircraft. Most often, the aircraft configuration must be retrofitted to accommodate a modification. As a modification affects more subsystems, cost and complexity increases dramatically, since each subsystem requires additional interface tailoring. If an initial aircraft configuration was designed so that future modifications would force only minimal changes in related aircraft subsystems, the cost of modification could be drastically reduced. The Boeing Commercial Airplane Company found that adding certain structural modification prerequisites to their aircraft during production would significantly reduce the need for aircraft modification retrofitting later (ADPA, 1980:44).

One could summarize a sound modification strategy as (1) organizing and integrating modifications into an orderly and efficient long range plan that will increase modification efficiency and reduce the gap in readiness between deficiency recognition and modification

implementation, and (2) pre-planning modifications into an aircraft by incorporating structural modification prerequisites so that the aircraft may efficiently be modified in response to changing states of threat, technology, and mission requirements. This strategy of pre-planning for future modifications will alleviate many of the current deficiencies in the USAF modification management process and markedly increase the U.S. ability to efficiently translate new technology into deployed military capability.

Recent Developments in Pre-Planned Product Improvement

Pre-planning an aircraft to accommodate future modifications is a new strategy for the services, but industry has used the strategy quite successfully. The Defense Science Board researched modification pre-planning in commercial aircraft production and recommended the strategy for,

> . . . military systems acquisitions where the degree of technical risk need not be high, or where a reduced-requirement initial configuration, followed by small-step enhancements of performance in later production units, makes sense [DSB, 1978:28-30].

The American Defense Preparedness Association (ADPA) researched the strategy and labeled it Pre-planned Product Improvement (P^3I). However, ADPA found that the strategy had greater benefits than just improving readiness and reducing modification costs (ADPA, 1981:3). The Boeing Commercial Airplane Company has used the P^3I strategy in virtually all of its aircraft designs beginning with the Boeing 707. The Boeing Aerospace Company also used the strategy in the design of the Air Launch Cruise Missile (ALCM). In the military, the F-16 Multi-national Staged Improvement Program (MSIP) used the strategy to reduce the cost of future

improvements. General Dynamics used the strategy for the F-16XL. Thus, there is a base of industrial P^3I experience and a small amount of military P^3I experience available for research.

In March 1981, Deputy Secretary of Defense, Frank C. Carlucci, directed a,

> . . . 30 day assessment of the Defense acquisition system, with the priority objectives of reducing cost, making the acquisition process more efficient, increasing the stability of programs, and decreasing the acquisition time of military hardware [Carlucci, 1981a:1].

For the assessment, studies of the acquisition process were reviewed, including studies by the Defense Science Board, the services, and industry. The views of industry were expressed by the Council of Space and Defense Industrial Association, who represented,

> Prime and subcontractors, large and small companies, and military systems covering aerospace, electronics, ships, computers, and combat vehicles [Puritano, 1981:3].

The assessment was summarized into 23 recommendations for improving the acquisition process and labeled the Carlucci Report. The first recommendation was a set of management principles in which P^3I played a prominent role. Recommendation two, in fact, was devoted exclusively to P^3I acquisition alternatives.

President Reagan, through his Secretary of Defense, Casper Weinberger, has endorsed the Carlucci recommendations and directed that the services implement P^3I (Carlucci, 1981a). On July 6, 1981, Deputy Secretary of Defense Carlucci began implementation by directing that the services select focal points to identify potential P^3I programs. He also gave the services guidelines to select P^3I programs (Carlucci, 1981b). However, P^3I implementation will require a fundamental change

in DOD acquisition strategy, which has yet to be accomplished or even firmly programmed.

P^3I Literature Review

A broad literature review of the subjects "pre-planned product improvement," "strategic planning," "product planning," "product improvement," "modular design," "aircraft design," and "aircraft modification," taken from the AFIT Library, the Wright State University Library, the Defense Technical Information Center, the GAO & USAF/IG Reports Office, the Air Force Business Research Management Center, the Office of Asst DCS/Plans and Programs for Development Plans, Hq AFSC, the Defense Science Board, ARINC Research Corporation, and the Office of Under Secretary of Defense for Research and Engineering provided an abundance of studies about the USAF modification process, which were highlighted earlier in the chapter. However, very few references to a general strategy for long range system improvement emerged. Lack of these references indicates (1) the DOD has not formalized a long range plan for weapon system improvement and (2) pre-planning improvement into an initial system design has not been formalized in university engineering or architecture curricula, even though pre-planning is practiced by industry. In fact, examples of pre-planning come largely from industry.

The Defense Science Board studied methods to improve industrial preparedness and reduce the cost of DOD acquisitions. Their Summer 1977 Study, Report of the Acquisition Cycle Task Force, notes that commercial aircraft programs, and the Boeing Company in particular, often preplan future improvements into their commercial aircraft configurations to make their aircraft flexible to changes in technology and market

demand and also to reduce the cost of future improvements (DSB, 1977: 28-30). Similarly, their Summer 1979 Study, Reducing The Unit Cost of Equipment, compares the history of the military KC-135 and commercial 707. Both aircraft were developed from a common aircraft parent. However, Boeing realized that to retain its 707 market share, as competitors introduced new aircraft, the 707 would require improvement. Boeing began to build 707s with prerequisites for increased cargo capacity, increased thrust, expanded wings, etc. Prerequisites helped to reduce modification costs as well as make changes in the production line easy; improved aircraft could be produced with little affect on recurring costs and without interrupting the 707 learning curve. Had the KC-135 followed the evolution of the 707, the KC-135s in the USAF inventory today would have the capability for 40% to 60% more fuel transfer at a 2000 mile radius, plus a significant reduction in takeoff roll (DSB, 1980:119; Steiner, 1981b). ADPA became interested in P^3I, in part, as a result of these Defense Science Board Studies.

In February 1980, ADPA began to publish articles in National Defense, explaining P^3I (originally named Modular Evolutionary Development). Dr. Walter LaBerge, Principal Deputy Under Secretary of Defense for Research and Engineering, asked ADPA to gather together the country's most knowledgeable corporate and DOD acquisition officers to discuss the merits of P^3I and recommend a course of action for P^3I implementation by the DOD. In response, in April 1980, ADPA and the Defense Systems Management School sponsored a three-day P^3I Seminar & Workshop that included 250 acquisition officers from industry and the DOD. The ADPA P^3I Seminar & Workshop Proceedings, available from ADPA, offer the most

authoritative and comprehensive P^3I discussion available. The January 1981 issue of National Defense published three articles that discussed the ADPA P^3I Seminar & Workshops: "Pre-Planned Product Improvement," by Dr. Hylan B. Lyon, Chairman of the ADPA P^3I Committee; "P^3I Competition, Standardization, and Systems Engineering," by Joseph F. Grosson, Executive Director for Acquisition, Naval Material Command; and "P^3I An Idea Whose Time Has Come .... Again," by Norman R. Augustine, Vice President, Operations, Martin Marietta Aerospace. These articles advocate P^3I but do not present the complete findings of the P^3I Seminar & Workshops. Also, editorials by William H. Gregory, "Mods and Pods" (Gregory, 1980:11) and "Streamlining the Acquisition Process" (Gregory, 1981:9) commented on P^3I in Aviation Week and Space Technology. With the exception of the ADPA P^3I Seminar & Workshop Proceedings these studies and articles present only an overview of P^3I.

P^3I Definition

The ADPA P^3I Seminar & Workshop defined P^3I in three parts:

> P^3I is a systematic and orderly acquisition strategy beginning at the systems concept phase to facilitate evolutionary cost effective upgrading of a system throughout the life cycle to enhance readiness, availability and capability.
>
> The modular baseline configuration design shall permit growth to meet the changing threat and/or to take advantage of significant technological and/or operational opportunities through future modifications or product improvements at appropriate time intervals.
>
> The baseline technological risk will be minimized and provide early availability by utilizing well known and established technology to the maximum extent feasible, limiting advanced technology to the subsystem(s) offering substantial operational or cost benefits [Lyon, 1981a:22].

This thesis will use the above definition to describe P^3I.

Research Objective

The research objective of this thesis is to evaluate existing program examples that use P^3I as a strategy for long range system improvement and to develop policy and procedures for formal P^3I implementation by the services.

Research Questions

P^3I is a process that can be applied to both commercial and DOD programs, yet these programs operate under different procedures and assumptions. P^3I must first be understood as a generic process in itself, before studying it in DOD or commercial applications; commercial P^3I practices cannot always be transferred directly into the DOD acquisition system. In either application, P^3I must be further tailored to each program; different programs will emphasize different facets of P^3I. Finally, P^3I highlights a major problem in DOD: planning long range improvement and managing its accompanied uncertainty. To investigate these concerns, literature reviews and interviews will focus directly on the following research questions:

1. What is the nature of P^3I as a process in itself?
2. What is the role of P^3I in each program example?
3. How can the inherent uncertainty that accompanies long range improvement be managed.

CHAPTER III

RESEARCH METHODOLOGY

Scope and Limitation

Although P^3I appears to be a straightforward concept, its implementation into the DOD acquisition system may be very complex and could generate a multitude of unforeseen problems. For this reason, Dr. Walter LaBerge, Principal Deputy Under Secretary of Defense Research and Engineering, asked ADPA to sponsor a P^3I Seminar & Workshop: to assess P^3I implementation concerns and recommend solutions. ADPA divided the seminar into eight workshops. Each workshop discussed a different P^3I implementation concern:

I. Incentives for Pre-Planned Product Improvement

II. Criteria for P^3I and New Starts

III. Approval Process

IV. Competition Between P^3I and New Starts

V. Industrial Competition in Product Improvements

VI. Product Improvement For Reliability and Maintainability

VII. Logistics Impact of Product Improvement

VIII. Other Impediments to Product Improvement (ADPA, 1980:1).

Taken together, ADPA considered these eight workshops to include all potential P^3I implementation concerns. The findings of each workshop were not intended to be the final answer to P^3I implementation, but do offer a starting point to understand P^3I and to form a basis for further research.

A common problem thread running through these eight workshops was the problem of long range uncertainty. Every program is faced with uncertainties as it begins in the conceptual phase and transitions through validation, full scale development, production, and finally deployment. P^3I recognizes program uncertainty past the deployment phase and into an "improvement phase," which lasts essentially for the entire life of the system. In the improvement phase, there always exists the possibility that a planned improvement will be cancelled or itself modified before it is implemented. Inherent in the P^3I definition, the decision to improve a weapon system is based, in part, upon states of threat, technology, and mission requirements. These states are uncertain in the future, especially in the context of military planning; not only can changes in these states force improvement cancellation, but political, budgetary, or other factors may also affect the direction of future improvements.

In past acquisitions, the primary approach taken to manage long range uncertainty has been to plan only in the short range, since only here are states of threat, technology, and mission requirements well known. This approach may still be valid for some programs where the uncertainty or cost of planning for future improvements is very high. However, in programs where the services do implement P^3I, the services will be required to plan beyond the short range, and must be able to manage the long range uncertainty of improvement cancellation.

Improvement uncertainty can be managed in a variety of ways. Formalizing the P^3I strategy into the DOD acquisition system, receiving support from Congress and the DOD, and budgeting funds for future

improvements into the Planning, Programming, and Budgeting System have been suggested by the ADPA P^3I workshops (ADPA, 1981:Recommendations). Perhaps even more important is the actual choice and plan of improvements. A program may have the complete support of the acquisition community, yet if threat, technology, or mission requirements change, a planned improvement may not be required, and simply cancelled. This thesis focuses on the actual choice and plan of improvements as the necessary base from which to manage improvement uncertainty.

Study Framework

The study framework will include an initial effort to establish a broad understanding of the P^3I process. Next, selected P^3I examples will be examined, to gain an understanding of how the P^3I process was applied to each program, and then to understand how each program manager was able to manage improvement uncertainty by selecting and planning appropriate improvement candidates. This study framework will mirror the three research questions and form the outline for the findings and conclusions chapters. Research question three poses a particularly complex issue which requires further breakdown. Initial P^3I research revealed that the following selecting and planning factors directly relate to managing long range improvement uncertainty; (1) threat, technology, and mission requirement forecasts; (2) risk of improvement cancellation; (3) reward/cost of pre-planning; and (4) other factors. These factors will be studied to see how they affect the selection and planning process and minimize long range improvement uncertainty.

Data Collection Plan

Literature Review

Data collection will begin with a more highly focused search for P^3I literature, P^3I examples, and P^3I related acquisition studies. It was earlier stated that few references to P^3I are available; however, there is a base of industrial P^3I experience and a small amount of military P^3I experience to draw from. This review will first focus on recognized P^3I examples, then on planning and modification examples not recognized to be P^3I, but potentially holding some lesson for the process. Also, an in-depth review of the ADPA P^3I Seminar & Workshop Proceedings will play a prominent part in the review. Once P^3I literature, P^3I examples, and P^3I related acquisition studies have been collected, they will be reviewed and specific P^3I examples chosen. Once these examples are chosen, source documents and interviews explaining these examples will form the basis for an in-depth P^3I study.

Interviews

The P^3I literature review will identify as interview candidates those individuals who have exceptional P^3I expertise and experience. As an example, organizers of the ADPA P^3I Seminar & Workshops and seminar attendees are possible interview candidates. Once P^3I program examples are selected, source documents describing these programs will identify program managers and other individuals responsible for directing P^3I in each program and selecting and planning appropriate improvements. Further, interviewees may suggest other sources of information. As P^3I experts, interviewees may offer a broad range of information relating P^3I to their specific programs, especially since so little has been

published about P^3I. The interview will encourage interviewees to share a broad range of P^3I information; however, within this broad framework of discussion, research questions one, two, and three will be specifically addressed.

Data Analysis Plan

The literature review will provide one source of P^3I findings; interviews will either support or not support those findings. Findings that are not consistent in both literature reviews and interviews will be evaluated. Thus, P^3I literature and interviews will provide a base of P^3I data for evaluation (research question one). P^3I examples will be compared and contrasted to gain an understanding of how P^3I was applied to each program example (research question two). The four selecting and planning factors will then be compared and contrasted to see how various degrees of these factors contribute toward managing improvement uncertainty. Given that these factors sufficiently explain the selecting and planning process, a model will be constructed to describe this process (research question three).

CHAPTER IV

FINDINGS

Initial Research

Early P^3I Literature and Interviews

The most extensive account of P^3I is presented in the ADPA P^3I Seminar & Workshop Proceedings. These proceedings were summarized and briefed to DOD, GAO, OMB, and the services by General Henry A. Miley, Jr. (USA ret.), ADPA President, and Dr. Hylan B. Lyon, ADPA P^3I Committee Chairman (Lyon, 1981b). Their Summary Briefing is included as Appendix B, and offers a condensed version of the seminar findings. On July 6, 1981, Deputy Secretary of Defense Carlucci directed by memorandum that the services implement P^3I. The Carlucci Memorandum is included as Appendix C, and lists a P^3I definition, objectives, applications, and application criteria, as well as proposed changes to DODD 5000.1, Major System Acquisitions and DODI 5000.2, Major System Acquisition Procedures.

The literature review identified individuals with P^3I expertise. Dr. Lyon is recognized as one of this country's leading P^3I authorities, leading to his work as the ADPA P^3I Committee Chairman. Top level OSD officials consulted regularly with Dr. Lyon for advice and direction as P^3I was staffed for DOD implementation (Baldwin, 1981). A series of personal and telephone interviews with Dr. Lyon to discuss P^3I and review ADPA P^3I documents were conducted. Another P^3I expert, Mr. Leonard Sullivan, assisted in organizing the ADPA P^3I Seminar & Workshop. Mr. Sullivan was formally Principal Deputy Director of Defense Research and

Engineering (1972-1973) and Assistant Secretary of Defense for Program Analysis and Evaluation (1973-1976) and contributed to many DOD acquisition studies. He is currently serving as a national security consultant to DOD in Washington, DC. Mr. Sullivan was interviewed by telephone.

The literature review identified Mr. John E. Steiner, Vice President, Corporate Product Development, The Boeing Company, as a dominant leader in the development and production of the Boeing family of commercial aircraft. Positions held by Mr. Steiner include Design and Program Head of the initial 727 Program and Vice President, General Manager of Production, for the 707, 727, and 737 Programs. He also served as Vice President, Product Development, during the initiation of the 747 Program. Mr. Steiner is highly recognized by the aerospace and transportation industries and was chosen "Man of the Year" in 1964 and again in 1972 by Aviation Week and Space Technology. Personal and telephone interviews with Mr. Steiner, and his Development Study Manager, Ms Louise K. Montle, were conducted.

The literature review and interviews with Dr. Lyon, Mr. Sullivan, Mr. Steiner, and Ms Montle provided much of the data necessary to answer research question one, concerning the nature of P^3I and also provided background for selecting P^3I program examples.

Selection of P^3I Program Examples

The research identified various P^3I program examples. The Boeing 727 aircraft program was selected as a P^3I program example because the 727 is representative of the Boeing P^3I process, which is on-going and applicable to the entire Boeing aircraft family. Also, because of Boeing's military and civilian roles, Boeing's P^3I process

may have potential application to DOD aircraft acquisitions. Both the DOD and Boeing have made large investments in aircraft improvement, and while DOD aircraft may perform more complex and demanding missions, there are elements of commonality in all aircraft that could make the Boeing P^3I process potentially useful to the DOD.

Mr. Steiner has written a number of publications that describe Boeing's P^3I strategy and the Boeing 727. These include: "Commercial Transport Aircraft Trends: Present and Future," published by the Center For Advanced Engineering Study, Massachusetts Institute of Technology; "The Economics of Technological Advancements," published by the International Civil Aviation Conference, Paris, France; and "Jet Aviation Development: One Company's Perspective," published by the National Air and Space Museum, Smithsonian Institute. Mr. Steiner also provided Boeing documents that describe Boeing's P^3I strategy and the Boeing 727: "An Overview of The Boeing Company," published by Boeing, and Case Study in Aircraft Design, The Boeing 727, published by the American Institute of Aeronautics and Astronautics. Information from these papers will be presented later in the findings.

General Alton Slay, Commander, AFSC, requested permission from Boeing's Chairman of the Board, Mr. T. A. Wilson, to send six USAF officers to the Boeing Aircraft Company in Seattle, Washington, to study Boeing's commercial practices. Lt Col Robert Pratt, Hq ASD, studied manufacturing and P^3I while at Boeing and wrote a brief summary concerning Boeing's P^3I process in the 1980 Commercial Practices Program, published by Hq AFSC (Pratt, 1981a:B5). This publication summarizes six months of study at Boeing and is an additional source of data. As

an outside observer of Boeing's P^3I process, Lt Col Pratt was an essential source for data collection; a series of personal and telephone interviews were conducted with him.

A second P^3I program example was suggested by Mr. Steiner and Ms Montle: the Boeing ALCM. For ALCM research, Mr. Steiner arranged an interview with Mr. J. R. Utterstrom, Vice President and General Manager of the ALCM Program. Mr. Utterstrom has worked for Boeing since 1948 with 15 years of experience on Boeing 707, 727, and 737 Commercial Aircraft Programs. Before transfer to the ALCM Program, Mr. Utterstrom was Director of Engineering for the Boeing 737 (Utterstrom, 1981). Mr. Utterstrom is an authority on Boeing's P^3I process and naturally incorporated P^3I into the ALCM design; even though the ALCM P^3I design is more subtle than other Boeing programs since USAF did not include improvement planning in initial ALCM specifications. Nothing in the "ALCM Program Management Plan" directs a P^3I strategy and Mr. Howard Campbell, USAF's Chief Functional Engineer for ALCM, agreed that provisions for P^3I were very limited (Campbell, 1981). The importance of choosing ALCM as a P^3I program example is in the fact that ALCM illustrates that P^3I can be accomplished within strict USAF design specifications, without an extensive knowledge of threat and mission forecasts, and without a formal DOD P^3I policy. The example also illustrates that the commercial program manager is the key individual to direct P^3I in his program.

A third P^3I program example suggested by the literature review and interviews was the General Dynamics F-16. Like ALCM, the F-16 was not formally identified by USAF for P^3I; however, "Engineering Change Proposal (ECP) 0350, Early Provisions for Improved Capability," directed

the beginning of a P^3I-type effort. Major William W. Morris, F-16 MSIP Program Manager, realized early in the production of the F-16 that proposed avionics and systems improvements would not easily integrate into the F-16; the aircraft would need to be drastically retrofitted to incorporate proposed improvements. Major Morris, working with the General Dynamics F-16 Program Manager, Mr. D. M. Hancock, reasoned that future avionics improvements could be made cost-effective (alleviating the requirement for massive aircraft retrofitting) if certain modification prerequisites were included in the original aircraft production design. Those prerequisites were included in production by ECP 0350. Like other P^3I examples, the F-16 illustrates that P^3I can be done within program specifications and within cost constraints, and that the program manager is a key figure to direct the P^3I effort, even without formal DOD P^3I policy.

Publications that explain the F-16 MSIP include: the "F-16 MSIP Program Management Plan," the "F-16 MSIP Test and Evaluation Master Plan," the "F-16 Weapon System Master Modification Plan," and "Engineering Change Proposal 0350, Early Provisions for Improved Capability." In addition, personal interviews with Major Morris, and Mr. D. A. Osborne, F-16 Financial Manager, were conducted.

In summary, three P^3I program examples were chosen; the Boeing 727, the Boeing ALCM, and the General Dynamics F-16. Publications and interviews that describe these program examples were evaluated and all three appear to have sufficient information available to warrant their selection.

The Nature of P^3I

P^3I is not a new concept, it is simply a common sense approach to system acquisition (Lyon, 1981b). For simple systems, P^3I can easily be applied; any product built to accept options and improvements has inherently used the P^3I concept. For example, many popular home computers are built for upgrade with a variety of growth features such as expanded memory, word processing, and other types of programs - both for practical use and home entertainment. However, application of P^3I to very complex systems, such as a military aircraft, requires a much more thorough systems analysis combined with long range planning. The primary basis of this type of analysis is found in the methodology of "structured programming". Structured programming originated as an architectural approach to computer software design. The end product of a structured program architecture is a set of modules that can be designed and modified with a high degree of independence. As a result, when a module is improved, the overall system need not be redesigned (Lyon, 1981b). Structured programming has evolved a great deal in both software and hardware applications. It remains a major part of many P^3I efforts, beyond its initial role as a precursor to present P^3I activity. More will be said about structured programming in the concluding chapter.

A formal definition of P^3I was presented in Chapter II, taken from the ADPA P^3I Seminar & Workshop Proceedings. The Carlucci Memorandum condensed this definition,

> P^3I is an acquisition concept which programs resources to accomplish the orderly and cost effective phased growth or evolution of a system's capability, utility, and operational readiness [Carlucci, 1981b].

How one "programs resources" to accomplish P^3I is different for each P^3I

project and should be the responsibility of individual program managers (Lyon, 1981b).

Dr. Lyon described the P^3I system within the boundaries of implementation as:

1. A threat-technical response - a basis for planning the evolution of system requirements.

2. System partitioning via structured programming - a basis for system design to minimize modification costs.

3. A program manager's plan for improvements - to be supported by the acquisition system as a basis to direct P^3I.

4. A funding basis for development and modification - a necessary prerequisite for weapon system improvement (Lyon, 1981b).

A description of P^3I attributes is given in the P^3I objectives in the Carlucci Memo, which tailors the findings of the ADPA P^3I Seminar & Workshops to defense needs. P^3I should:

1. Shorten the acquisition and deployment time for a new system or an incremental capability.

2. Reduce overall acquisition and operating and support costs.

3. Extend useful life of equipment.

4. Combat military obsolescence.

5. Reduce technical, cost, and schedule risk.

6. Accomplish orderly growth from initial to mature system reliability.

7. Reduce logistics and support problems entailed with new material introduction [Carlucci, 1981b].

These objectives parallel Dr. Perry's challenge ". . . to improve our exploitation of basic U.S. technology as we translate it into deployed military capability [Perry, 1981:II-34]."

The ADPA "P^3I Summary Briefing" splits "Program Management Objectives of P^3I" between initial start-up and continued program life. For

program start-up, P^3I program management objectives are to:

1. Reduce technological risk - initial requirements can be written for a shorter time horizon than a new start.

2. Insure capacity for growth - system performance growth through planned upgrades must be a basic part of initial evaluation.

3. Assure system architecture designed to accommodate growth - upgrades are planned by the program manager and interface control is a key management thrust.

4. Plan subsystem (module) characteristics designed to different time horizons than the main frame - subcontractors should compete to improve subsystems where appropriate (ADPA, 1981).

During program life P^3I management objectives include:

1. Program manager maintaining the P^3I plan.

2. R&D funds being programmed in timely a fashion to reflect upgrade packages.

3. Subcontractors competing to update systems selected for upgrading.

4. Program manager updating system level design features (ADPA, 1981).

ADPA emphasized that these objectives require certain fundamental design features:

1. Modular Systems.

2. Reserve Capacity.

3. Tight Interface Control (ADPA, 1981).

The non-program specific writings of P^3I thus include: definition, system description, general objectives, program-phased objectives, and three fundamental design features.

This general overview of P^3I sets the stage to examine individual P^3I program examples. An introduction will acquaint the reader with each program, followed by findings of the role of P^3I as it applies

to each program. Then the four selecting and planning factors will show how program managers were able to manage long range improvement uncertainty. Finally, a summary will tie the findings together.

The Boeing 727 Aircraft

Introduction

The Boeing Company is distinctly different from the DOD, yet there are some similarities in the procedures by which Boeing develops and the DOD acquires a new aircraft. Perhaps the most significant difference between the two is the manner in which a new aircraft is financed. Boeing must commit enormous sums of its own capital to develop a new aircraft. If a new aircraft is not well received by the airlines, Boeing could face potential bankruptcy, which has threatened not only Boeing, but most aircraft manufacturers (Steiner, 1980:1). As an example, Boeing committed almost $6 billion to their 757 and 767 aircraft development and manufacturing facilities well before the first aircraft was scheduled off the production line (Steiner, 1981b). If the 757 or 767 is not well received, Boeing will have substantial losses. Unlike Boeing, the DOD does not face a financial crisis if a program is cancelled. A service must pay a cancellation penalty to partially reimburse the contractor for his effort and investment, but the DOD replenishes its budget from the Federal Government and continues in the business of defense.

Given the risk of bankruptcy if a major aircraft program fails, Boeing, as well as all other aircraft companies, takes a very conservative approach toward developing and manufacturing a new aircraft (Pratt, 1981b). A company must be certain that a new aircraft will be well

received by the airlines, that it can be economically manufactured, and that customer demand cannot be met by improvements incorporated into existing aircraft (Steiner, 1980:13). If these conditions are met, there is tremendous profit potential. Boeing sells its aircraft at market prices, which naturally tend to increase with time and inflation. Boeing's recurring production costs tend to decrease with time due to a learning curve effect in production. The longer the production life of an aircraft, the greater the company's profit margin and return on investment (Pratt, 1981b). It is clearly to the best advantage of an aircraft manufacturer to continue production of an aircraft for as long as possible.

<u>The Role of P^{3}I</u>

An impediment to a long production life is the fact that other aircraft manufacturers compete and produce new or improved models causing a reduction in sales of older aircraft. For a long production life, one must constantly improve an aircraft (Steiner, 1981b). The cost of improvements can be quite significant, enough to negate any profits. By the time the 425th Boeing 727 came off the production line, improvement costs had amounted to 50% of the initial 727 development cost (Steiner, 1979:10). Therefore, Boeing had to hold down unit costs even while improving the aircraft to meet competition. Boeing realized that unit costs could be reduced by (1) making large capital investments for modernizing production, (2) ordering materials and parts in optimum quantities, (3) improving productivity, and (4) reducing improvement costs by pre-planning later improvements into their production line and aircraft (Montle, 1981). Pre-planning improvements permitted the

production learning curve to continue downward even though the production line was changed to manufacture an improved model (Steiner, 1981b).

The Boeing 727 illustrates the effects of pre-planning to lengthen production life. Since the Boeing 727 began production in 1960, three versions have been manufactured: the 727-100, the 727-200, and the Advanced 727-200 (Gregoire, 1978:61,66). Figure 5 depicts how the Boeing 727 has grown to increase fuel capacity by 62%, to increase thrust by 31%, and to increase gross weight by 37%. Also, the Boeing 727 was designed to incorporate a long list of options to satisfy a world-wide base of customers; over 1700 aircraft have been delivered to 99 different customers, making the 727 the most widely used commercial aircraft flying today (Boeing, 1981:727).

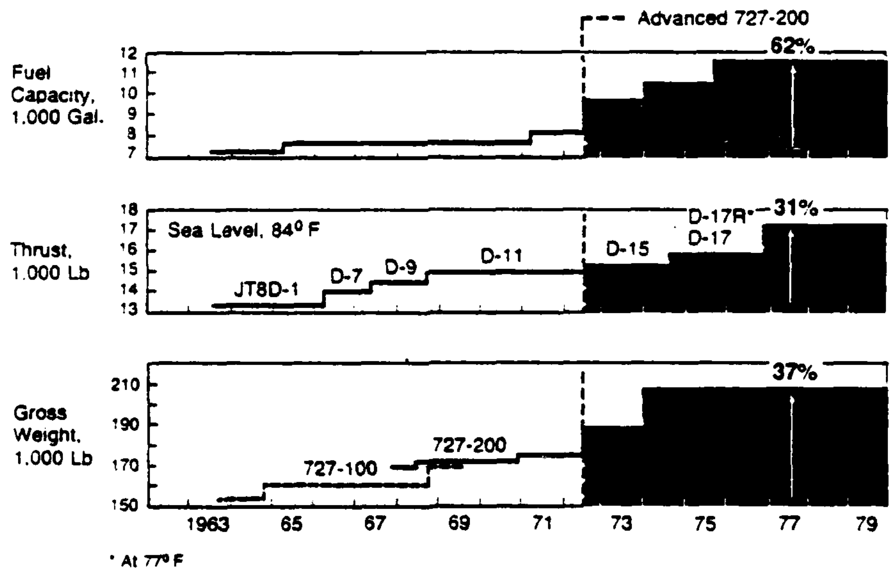

Figure 5

Boeing 727 Evolution
(Steiner, 1980:Fig.39)

An example of a Boeing P^3I aircraft application is illustrated by the Boeing design concept of "dollar sign tooling". Dollar sign tooling requires,

> . . . a formal contract between engineering and manufacturing (that) guarantees that certain surfaces will be maintained for tooling while other specified surfaces will be available for the engineer to change. This permits strength changes with essentially no manufacturing cost impact [Steiner, 1978:8].

For example, dollar sign tooling specifies that structural members such as wing chords, webs, and spars can be changed on the manufacturing line without changing their interface with the upper inspar skin of the wing (Figure 6). In other words, these structures can be redesigned and made stronger such that an aircraft can carry higher gross weights, with little change to the wing itself, thereby keeping increases in manufacturing costs low when the wing is strengthened (ADPA, 1980:56,57).

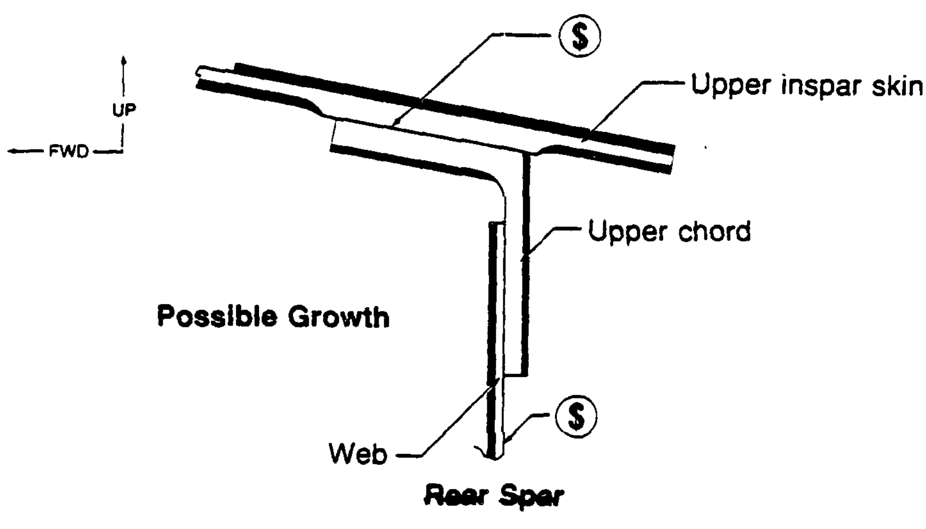

Figure 6

Dollar Sign ($) Tooling
(ADPA, 1980:5)

Managing Improvement Uncertainty

A significant impediment to the use of P^3I has been the prevailing "wisdom" of the industry that the inherent technological uncertainty of complex systems will inevitably overwhelm attempts at forecasting and planning changes in advance. Those P^3I efforts that have been accomplished have occurred not so much in defiance of this wisdom as from a realistic assessment that the organization involved had no economic choice but to try. Regardless of their reasons, certain groups have tried P^3I and lessons on managing long range improvement uncertainty can be derived from reviewing their results. In this case, Boeing's 727 aircraft provides one example.

Threat, Technology, and Mission Requirements Forecasts. Boeing's threat, while not as direct as the military threat, is no less real; it is the threat of a downturn in aircraft sales. Sales can be lost if a competing aircraft company, either U.S. or European, manufactures an aircraft that better fits the needs of commercial airlines. With increasing fuel prices, that need currently focuses on fuel efficiency. Also, any situation that decreases airline profitability, preventing the airlines from accumulating needed capital to finance future aircraft purchases, will potentially affect Boeing's sales. As examples, a general slowdown in the world economy, increased aviation fuel prices, or lengthy airline strikes could portend such a sales downturn. Figure 7, "Boeing 727 Production," depicts large fluctuations. Boeing has used the P^3I strategy to help forecast and pre-plan its production system with the capability to efficiently respond to large increases or decreases in sales, thereby reducing losses due to sales fluctuations (ADPA, 1980:50).

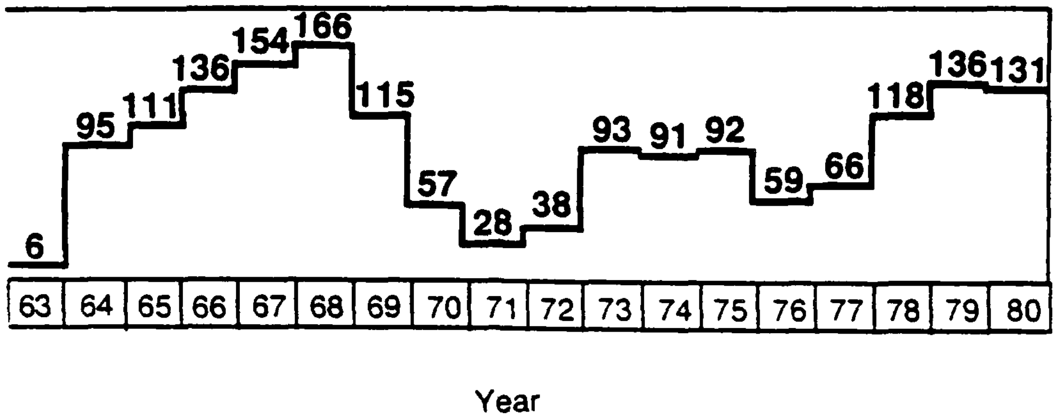

Figure 7

Boeing 727 Production
(Boeing, 1981)

The answer to the threat of a downturn in aircraft sales, in part, is aircraft improvement via advancements in technology. Technology can be forecasted and Boeing is using these forecasts to pre-plan their aircraft for improved fuel efficiency. Figure 8 depicts Boeing's technology forecasts and their expected effects upon fuel efficiency. Boeing actively pursues its own research to develop and apply new technology. For example, Boeing used over 1500 hours of wind tunnel testing, over a period of three years, to develop the 727 triple slotted flaps and slats that form a high lift system for high gross weight takeoffs and landings from short runways (Bowes, 1978:14-17).

Currently, Boeing has developed a number of improvements for the 727 that were pre-planned using technology forecasts:

1. Advanced composite material for secondary structure
2. Full regime autothrottle

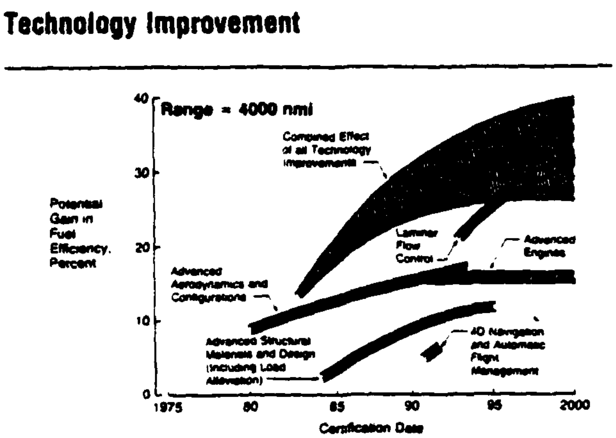

Figure 8

Technology Improvement
(Steiner, 1980:Fig.29)

3. New technology auxiliary power unit
4. Aerodynamic fairing improvement
5. Engine noise suppression
6. 727-200 freighter or convertible
7. Flight management system (Gregoire, 1978:69).

A major driver of such technology forecasting is mission forecasting. Each of the previously stated technological improvements is pursued only if there is a potential customer requirement that would be appropriately enhanced by the change. Since airline requirements are changing, Boeing works closely with the airlines to understand and forecast their needs (Montle, 1981). The P^3I design in the 727 makes it possible for Boeing to include particular options or changes in their aircraft very cost-effectively in response to individual airline

requirements. For example, Boeing tailor-made a fleet of 727s for All Nipon Airways, who had a flight requirement from Tokyo to Hong Kong. The aircraft required a 2000 nautical mile range, with 140 passengers, and a very high fuel reserve. The increase in weight over their standard 727 required major wing, body, and landing gear structure changes. As a similar example, increases in capacity were tailored in the 727 so Sterling Airways (the world's largest charter airline) could achieve a 2500 nautical mile range for a Stockholm-Las Palmas route (Gregoire, 1978:68). These tailor-made versions of the Boeing 727 were made cost effective, in part, because Boeing had pre-planned for these types of improvements in their production line and aircraft design using forecasts of sales, technology, and customer requirements.

Risk of Improvement Cancellation. Boeing found in its 707 Program that improvement costs could keep the program in a state of negative cash flow indefinitely (Steiner, 1981a:6). Therefore, Boeing has made a sustained effort to forecast and plan improvements. For example Boeing,

> . . . maintained an engineering group of between 500 and 1000 people dedicated to (P^3I) 727 improvements and customer special features during the entire 15 years since the first customer delivery [Steiner, 1978:8].

With careful planning, Mr. Steiner stated, "The risk of planning (improvements) is far smaller than not planning for it by a factor of ten, and payoffs are very large in the long term and can be the difference between a successful and unsuccessful program [Steiner, 1981b]." Boeing has found, in general, that the risk of any one improvement cancellation will not significantly impact a program financially, especially in the long run, when more improvements are likely. In contrast, to neglect

pre-planning for improvements can lead to program failure.

Reward/Cost Comparison of Pre-Planning. Although Boeing doesn't actually reduce numbers to a dimensionless ratio, they use a management concept for evaluating potential P^3I candidates that compares the rewards of pre-planning against the cost of pre-planning. The reward of improvement pre-planning may be thought of as the savings realized from reduced improvement costs when either the production line is modified to produce an improved aircraft, or an operational aircraft is modified and improved. Pre-planning reduces improvement costs by including in the production line and aircraft those prerequisites, either material or design, that make later improvement more efficient. With P^3I not only are improvement costs reduced, but production line and aircraft down-time are reduced, and Boeing is able to more easily adjust to the changing needs of the airline industry, thus helping to ensure a continued market and long production life for their aircraft. As Mr. Steiner stated, "The reward of improvement planning is very great, and can mean the difference between a successful and unsuccessful program [Steiner, 1981b]."

The cost of pre-planning must be thought of as a required capital investment; necessary if the program is to have a long life (Pratt, 1981b). There is no specific data available from Boeing that categorizes the extra cost of pre-planning because Boeing's P^3I process is integrated into their development/production system (Montle, 1981). However, Boeing has found ways to effectively reduce that cost so that often it is insignificant. Reducing pre-planning cost will be discussed under Other Factors. In the long term, as prerequisites are used again and again to reduce improvement costs, the reward/cost comparison becomes larger, and

in a successful program such as the 727 it is considered very large (Montle, 1981).

Other Factors. Boeing maintains that P^3I must begin in the conceptual phase of an aircraft program, influencing the evolving design of the aircraft and also the design of its production line. Then as sales, technology, and customer requirements are reassessed throughout the program life, (1) improvements are added, (2) the plan for future improvement candidates is updated, and (3) other prerequisites are added. In these respects, P^3I is an integral part of the Boeing development/production system and the two are mutually supportive. P^3I helps to make the development/production system more efficient by reducing risk, decreasing development/production time, and making improvements easier and more cost effective. Boeing's development/production system supports P^3I with technical-cost teams to identify potential improvements that should be anticipated and with labs that develop and apply new technology to implement improvements that have been pre-planned. Also, Boeing's P^3I process is in-place and on-going and Boeing has a continuity of 25 years of aircraft P^3I experience. These factors make Boeing's P^3I process increasingly efficient and help to reduce pre-planning costs.

Another efficiency factor, suggested by Lt Col Pratt, did not apply directly to the 727 program. In the present Boeing development/production system the use of computer aided design and computer aided manufacturing (CAD/CAM) has a large potential to increase P^3I efficiency. With CAD, one can design and test improvements on a computer before actually incorporating those improvements into the aircraft. CAD can reduce design time by producing ". . . more accurate drawings, rapid

response to changes, reduced initial engineering changes, and more cost effective tooling . . . [Pratt, 1981a:B5,6]." This is possible because a complete data base of all aircraft subsystem parameters is stored in the computer. A component can be changed or a modification added to the aircraft via computer, and the computer will identify how that change will affect all other aircraft subsystems. For example, if an aircraft engine is expected to be improved in later versions with an increase in thrust of 15%, that increase will affect many aircraft subsystems as well as impact such performance criteria as aircraft loadings, takeoff and landing capability, range, speed, and altitude. Affected subsystems and performance can be identified by computer, so that engineering and mission related changes can be pre-planned (Bernstein, 1981). Thus, when the engine is later improved, other aircraft subsystems will not necessarily have to be changed. This also makes possible easy identification of those prerequisites that offer the greatest reward/cost comparison.

As an example, the Boeing 767 wings are totally CAD designed. All engineering drawings, which included lofting, structures, wiring, plumbing for fuel and anti-ice, flaps, etc. were drafted on the computer and then tested for performance. By simulating flight characteristics, it was possible to design the wing for greater immediate fuel efficiency as well as provide design inputs for future wing modifications. The data base for this wing design was translated into the production line by CAM, and Boeing found that tolerances between CAM specified parts were far more exact than could be achieved manually (Pratt, 1981b). The CAD/CAM design capabilities are important to both efficient near-

term system design and to P^3I. In the near-term, trade-off of numerous parameters allow optimization towards a present mission. Inclusion of any future mission prerequisites affects some parameters directly and may snowball to countless others. The beauty of CAD/CAM lies in its ability to evaluate the parameters of the current mission and ascertain how sensitive they are to future changes. With the complexities involved, only computer assisted analysis can deal with these ramifications completely, both in design and production implementation.

Summary

The most significant factor reducing improvement uncertainty in Boeing aircraft programs is recognition that improvements must be pre-planned to ensure a long program life. The two are mutually supportive: pre-planned improvement leads to a long program life; a long program life provides the opportunity for continued improvement. However, without pre-planning in both the aircraft and production line, improvement can be so costly that program cancellation is warranted.

Once it is recognized that improvements must be pre-planned, forecasts of sales, technology, and customer requirements give direction to pre-planning to select improvement candidates. There is naturally a degree of uncertainty in forecasting, but that uncertainty can be reduced by continuously updating future forecasts. Boeing updates sales forecasts as a basis for production planning and remains aware of potential developments of competing aircraft manufacturers that could reduce their sales. Boeing not only updates technology forecasts, but develops and applies technology in their labs. Technical uncertainty is reduced as Boeing labs work closely with design engineers to develop pre-planned

improvements. Finally, uncertainty in customer requirements is reduced as Boeing works closely with a world-wide base of customers to evaluate their needs.

The P^3I process must begin early in the conceptual phase of an aircraft program, when these forecasts are evaluated to formulate an improvement plan and select prerequisites to support that plan. Prerequisites are incorporated into the initial aircraft configuration and also the production line so that massive retrofits are not required when older aircraft are improved or a new derivative is manufactured. Since prerequisites are based upon forecasts that are somewhat uncertain, prerequisites that allow for flexibility are emphasized to reduce improvement uncertainty. The concept of dollar sign ($) tooling, for instance, allows for structural strength changes within a wing. Those changes are not restricted to one particular strength, but a range of strengths so that a range of wing improvements can be made. As a similar example, the Boeing 747 was designed with the structural prerequisites to allow the aircraft to be stretched. As it turned out, the 747 was shortened rather than stretched, but those same prerequisites provided the flexibility to either stretch or shorten the aircraft with reduced cost (ADPA, 1980:68). Thus, prerequisites flexible to allow for a range of improvements reduce improvement uncertainty.

If a prerequisite for improvement is incorporated into an aircraft configuration or production line, there is still the small possibility that a particular prerequisite will never be used. By considering the prerequisite reward/cost comparison, one can further manage improvement uncertainty. For pre-planning with very high uncertainties, it

would seem logical to select only those prerequisites with very high reward/cost comparisons. Again using the concept of dollar sign ($) tooling as an example, there is basically little cost associated with holding the dollar sign surfaces constant. Yet there is potential for significant savings in strengthening the wing without changing the production line. Thus, by selecting prerequisites with very high reward/cost comparisons there is potential for large improvement savings with little extra cost, even when improvement is very uncertain. Further, Boeing has found that in the long range the aggregate that a prerequisite will reduce improvement costs increases significantly.

Finally, improvement uncertainty can be reduced if the P^3I process itself can be made more efficient, reducing the extra cost associated with pre-planning and thereby increasing the reward/cost comparison. Boeing's P^3I process is made more efficient because: (1) P^3I receives the support of Boeing's development/production system; (2) P^3I is an in-place and on-going process; and (3) Boeing has a continuity of 25 years of aircraft P^3I experience. Their current emphasis, CAD/CAM, has the potential to markedly increase pre-planning efficiency by allowing improvement design and testing via computer before improvements are incorporated in the aircraft.

The Boeing 727 program illustrates how Boeing used the P^3I strategy to manage long range improvement uncertainty. By continuously updating future sales, technology, and customer requirement forecasts; by selecting prerequisites that offer wide flexibility and a high reward/cost comparison, and by achieving efficiency in the P^3I process, there is reduced chance that prerequisites for improvement will not contribute

to a long program life and reduce improvement costs. As Mr. Steiner stated, there is more risk of program failure when not pre-planning (Steiner, 1981b).

The Boeing Air Launch Cruise Missile

Introduction

The Boeing ALCM was designed within a strict set of engineering and performance specifications. The missile presented a major challenge to integrate a variety of components i.e., the guidance system, engine, fuel, and ordnance, into a very compact body (Campbell, 1981). Provisions for growth, such as empty space, extra electronics, or extra fuel capacity was very limited. These conditions appeared to make ALCM a poor P^3I candidate. Further, if Boeing had overtly planned for growth in ALCM with extra hardware that did not directly contribute to ALCM's immediate mission, USAF would have rejected such hardware as "gold plating", diminishing Boeing's chance for contract award.

Even with such strict engineering and performance constraints, Boeing wanted to design ALCM to increase its chances for a long program life, thereby giving Boeing a greater return on its ALCM investment. Boeing reasoned if ALCM was designed to accommodate a variety of possible missions then USAF, other services, and perhaps even NATO countries might purchase ALCM and ALCM derivatives for many years to come (Steiner, 1981b). A P^3I design was needed to give ALCM that mission flexibility. Boeing recognized the importance of choosing an individual with a strong P^3I background to direct the ALCM P^3I effort. Mr. J. R. Utterstrom was chosen as ALCM Program Manager based upon his P^3I engineering efforts on Boeing 707, 727, and 737 Programs (Steiner, 1981b). The following is a

summary of the role of P^3I in ALCM taken from interviews with Mr. Utterstrom, Mr. Steiner, and Ms Montle.

The Role of P^3I

In the original ALCM proposal, USAF requested a missile with a 1000 nautical mile range. ALCM managers at Boeing reasoned that if the missile was to be deployed for rough terrain following and evasive side maneuvers, the 1000 nautical mile range would need to be extended by at least 30%. Also, another missile, the Tomahawk, already had a longer range and if ALCM was to be used for other missions its range might as well be extended to compete with the Tomahawk. Finally, new aircraft have historically been improved by extending range, and Boeing believed that ALCM would evolve similarly. Boeing reasoned that the only way to extend range (holding other mission parameters constant) would be to increase fuel capacity, which would require lengthening ALCM. Boeing could not simply attach an additional six or eight feet to the back of the missile; the basic structure would require redesign with possibly different strengths, support, and a different internal configuration. Using the P^3I strategy, Boeing designed the original ALCM as if it was to be later stretched into a longer version with increased fuel capacity for extended range. Thus, when the go-ahead was given to manufacture ALCM in a stretched version, redesign would be minimized.

Boeing correctly perceived the requirement to lengthen ALCM. USAF changed its ALCM proposal to extend range, which resulted in a definite advantage for Boeing, who was able to keep cost and schedule for redesign low. Boeing's performance on ALCM redesign had a significant and favorable impact upon the eventual decision of USAF to award

the ALCM contract to Boeing (Utterstrom, 1981).

Another P^3I example concerns the ALCM nose cone. If a missile is to have a good chance to reach its target, it must avoid detection by enemy radar. Radar avoidance can be increased if the missile nose has a very low radar reflectivity. A traditional method to achieve low radar reflectivity is to design a soft nose that will absorb radar waves rather than reflect them. However, a soft nose is very expensive to manufacture. To keep costs down, Boeing wanted to put a hard nose on ALCM. Also, a hard nose is less vulnerable to any debris in the air, especially at very high speeds. A hard nose could be used only if it could be shaped to minimize radar reflectivity; Boeing set out to shape such a hard nose. Boeing found that the shape of the nose dictated the circumference of the missile, which in turn constrained the internal configuration of the missile. Using the P^3I strategy, Boeing pre-planned the shape of the missile and its internal configuration to interface with the shape of a hard nose, confident that one day the hard nose would be fully developed, tested, and attached to ALCM. To win the contract award, Boeing placed a soft nose on ALCM in order to demonstrate that ALCM can be produced now, using a soft nose with low reflectivity. Thus, by using the P^3I strategy, Boeing will not have to redesign ALCM's shape and internal configuration when the hard nose is attached.

Another P^3I example is illustrated by the small wings on ALCM, called elevons. Current elevons are shaped to give ALCM specific flight characteristics at current mission speeds and altitudes. If the ALCM mission changes, the elevons will likely be redesigned to fit each particular mission. For example, an extended range and low speed mission

would require larger elevons with more lift, and a high speed mission would require smaller, tapered elevons with less drag. To give ALCM this flexibility in terms of elevons, Boeing fastened the elevons to ALCM using eight accessible bolts, rather than permanently bonding the elevons so that they could never be changed. This elevon design will help to make elevon conversion easier in the field, and Boeing's production line will not have to be changed when manufacturing ALCM derivatives (Utterstrom, 1981).

As another example of P^3I, Boeing considered that if ALCM was used in a mission requiring a higher speed, the air intake for the engine would require a lower throat mach number to prevent compressor stalls. Historically, as other jet engines have improved and evolved, their speed has increased and their air intakes modified to allow for higher speeds. Boeing designed the ALCM air intake with a low throat mach number, so that when ALCM is employed in higher speed missions, the air intake will not require modification.

As a continued improvement effort, Boeing developed an engine replacement for ALCM which increases thrust 57% over the present engine. The new engine is designed to simply "drop in" the present ALCM engine compartment, with no other changes to the missile.

Other P^3I examples include the fact that ALCM was required to be carried on the B-52, but Boeing also designed ALCM to be carried on the B-1. Finally, Boeing was able to reserve a small amount of free space for incorporation of future electronic countermeasure components (Hanbrich, 1981).

Managing Improvement Uncertainty

Threat, Technology, and Mission Requirements Forecasts. Boeing was well aware of future technology forecasts, by virtue of its use of these forecasts in aircraft development. However, Boeing had a limited knowledge of future threat and mission requirements since these forecasts were classified and not made available to Boeing. Therefore, Boeing looked at historical aircraft trends in combination with potential ALCM missions to forecast ALCM evolution (Steiner, 1981b). Boeing's goal was not to fit ALCM to a particular future design, but make ALCM flexible enough to fit into a variety of possible mission scenarios, both from a U.S. and NATO perspective. Boeing made an educated guess of the many potential threats and missions that ALCM might be used for and the future needs of both U.S. and NATO users then designed ALCM with USAF specifications, yet made it flexible enough to accommodate changes for these variety of other missions.

Once Boeing had identified potential mission scenarios, they began to actively develop and apply new technology to make ALCM's flexibility a reality; development of a new engine is one example. Designing ALCM to fit into the B-1 is another. Also important was the development of a new nose cone to decrease production costs. It is important to note that these are design studies and CAD analyses, and only minimal impact is seen on the current ALCM design. Those few accommodations necessary come at no expense to the current mission. Boeing has pursued their forecasts by using their own resources to develop and apply technology to P^3I as an investment that will increase the likelihood that ALCM will be used in a variety of mission roles - attempting to

ensure a long production life and increase profitability (Montle, 1981).

Risk of Improvement Cancellation. Risk of improvement cancellation for ALCM is very similar to the risk of improvement cancellation for other Boeing aircraft programs; in the long term that risk is small, and is not grounds to neglect pre-planning. The longer the ALCM program life, the greater the likelihood that ALCM will be improved. Risk is further minimized if ALCM can be designed for flexibility; if a prerequisite is applicable to a wide range of improvements, then the risk that such a prerequisite will never be used is even smaller. As an example, a prerequisite for elevon change is the ability to easily remove and replace the elevons, which is made possible by a set of eight accessible bolts. It is not necessary to know the exact nature of future missions and elevon changes now, only that there is a very good chance in the future that the elevons will be changed. The eight elevon bolts are then a prerequisite for many different types of missions, and if ALCM derivatives are manufactured and the elevons changed, the eight bolts will provide a substantial savings in improvement costs.

Mr. Steiner's statement concerning the risk of aircraft improvement planning applies to ALCM. The risk is greatest when neglecting to plan for improvements, since pre-planning will often make the difference between a successful and unsuccessful program (Steiner, 1981b).

Reward/Cost Comparison of Pre-Planning. As in the 727 example, the reward of pre-planning for ALCM is two-fold: the rewards of more efficient improvements, such as reduced cost and shorter production adjustments, and the potential of an increased production life with greater

returns on investment. Boeing has already begun to realize the benefits of P^3I, as they designed the original ALCM for a stretch capability that helped them to win the ALCM contract. Also, the built-in flexibility to adapt to other missions may make sales to other services and NATO countries a possibility, increasing production life and profitability.

The cost of pre-planning was not significant for ALCM, compared to the overall investment Boeing committed to ALCM development. Even before Boeing had won the ALCM contract, it had committed over $5 million to ALCM (Montle, 1981). It is difficult to identify the cost of pre-planning because Boeing's development and production system has thoroughly integrated P^3I. Since Boeing has had extensive P^3I experience in aircraft design and manufacturing, Boeing naturally transferred that experience to the ALCM through the program manager without extra cost. Further, the overall cost of pre-planning could not be high if Boeing was to competitively price ALCM. These facts lead one to conclude that even though Boeing could not release costs of ALCM pre-planning, that cost was not high.

The potential reward/cost comparison of improvement pre-planning for ALCM should be judged in the long run. If ALCM is successful with a long production life and many improvements, this ratio has the potential to be very high since pre-planned improvements offer substantial savings over unplanned improvements. If ALCM has a short production life, then it is possible that Boeing will realize a loss on the costs of pre-planning, but that loss will not be significant, since the extra costs of pre-planning were low.

Other Factors. Factors that contribute to reducing improvement uncertainty in the ALCM are essentially the same factors in the 727 example: (1) P^3I is supported by Boeings development/production system; (2) P^3I is an in-place and on-going process; and (3) Boeing has the continuity of a long P^3I experience. CAD/CAM increases the efficiency of design planning, and was used to design the shape of the nose to minimize radar reflectivity.

Summary

Boeing's experience with ALCM, P^3I, and improvement uncertainty is similar to the 727 example, but there are differences. First, Boeing recognized that pre-planning was required to give ALCM the potential for a long program life. Boeing had very little knowledge of DOD threat and mission forecasts to pre-plan improvements; they relied upon historical aircraft trends and their best estimates of potential ALCM missions. Boeing was well aware of technology forecasts, and has already begun to plan ALCM derivatives by developing and applying new technology, reducing technical improvement uncertainty. Thus even with limited opportunity for P^3I, Boeing was still able to design ALCM with some flexibility and reduce improvement uncertainty. The risk of improvement cancellation, as in Boeing aircraft programs, is not significant when viewed in the long term and not justification to neglect pre-planning. There is more risk of program failure if pre-planning is neglected. The reward of reduced improvement cost and a long program life make P^3I a perceived necessity for Boeing's profitability. The cost of ALCM pre-planning was low, in part, because pre-planning was limited. Thus, the reward/cost ratio for improvement pre-planning is potentially very high,

which further justifies pre-planning when there is great uncertainty. Other factors, such as Boeing's development/production system, the in-place and on-going P^3I process, and Boeing's continuity of P^3I experience help to make P^3I more efficient and reduce the cost of pre-planning, thereby increasing the potential reward/cost comparison. Finally, CAD was used to shape the nose of ALCM, which also contributed to design efficiency. These findings, taken together, illustrate how Boeing used the P^3I strategy to manage long range uncertainty in a program with a very limited potential for P^3I and with a limited knowledge of future requirements.

The General Dynamics F-16

Introduction

The F-16 was originally developed to be a simple, lightweight, fighter aircraft with air-to-air and air-to-surface weapon delivery capability for the Air Forces of the United States, Belgium, Denmark, the Netherlands, and Norway (ASD/YPPP, 1981:1-1). The F-16 offers good performance, reliability, and maintainability at a cost that is less, compared with other USAF fighter aircraft (Schemmer, 1981:59). Performance advantages are made possible, in part, because the aircraft is simple and lightweight. Extra provisions for aircraft growth to meet new mission requirements were not deemed compatible with the initial F-16 concept (Morris, 1981).

The F-16 was developed to play a major role in tactical warfare in a NATO-Warsaw Pact confrontation. As the Soviets have increased the sophistication of their weapons, the Warsaw Pact threat has become a reason to upgrade the capabilities of the F-16.

The threats faced by European Theatre Tactical Air Forces are increasing in numbers and sophistication, providing the Warsaw Pact with a greater capability to fight the combined air/land battle. This established trend dictates a clear need for continuing improvements in tactical air systems. In response, tactical force planners have identified key mission needs as:

1. Day Precision Strike

2. Night and In-Weather Attack

3. Low-Level In-Weather Penetration

4. Beyond-Visual-Range Air-to-Air Intercept [General Dynamics, 1980:ii].

In response to these mission needs, TAC and NATO decided that avionics and other system improvements now in development might have a potential home in the F-16. These improvements would not be fully developed and operational until the late 1980s and would be added to the aircraft as modifications. These improvements are:

1. Advanced Medium Range Air-to-Air Missile (AMRAAM) - a beyond visual range radar guided missile.

2. Airborne Self Protection Jammer (ASPJ) - an active internal electronic countermeasures system.

3. Global Positioning System (GPS) - a satellite based navigation system used to determine vehicle position and velocity with extreme accuracy.

4. Joint Tactical Information Distribution System (JTIDS) - a battlefield information display network.

5. Low Altitude Navigation and Targeting Infrared for Night (LANTIRN) system - an all weather laser-augmented navigation, target acquisition, and weapons delivery system.

6. SEEK TALK Radio System - a jam resistant and secure UHF radio system.

7. 30MM Gun Pod - an anti-armor capability for TAC aircraft (ASD/YPDT, 1981:31).

Further, these improvements involve development by 12 different companies.

It will be no simple task to integrate one or more of these improvements into the F-16 when they are finally developed. Mr. D. A. Osborne, F-16 Financial Manager, stated that the cost of after-the-fact modification would be extremely high, and in fact prohibitive, because the aircraft will need to be thoroughly dismantled and retrofitted to accommodate each improvement. To reduce the cost and down-time of F-16 modification, the existing planning group added improvement prerequisites to the aircraft beginning with production model #330, and whole subsystems beginning with production aircraft in July 1984.

The Role of P^3I

Early in the production program the F-16 System Program Office (SPO) recognized the magnitude of problems that would result if these F-16 improvements were managed according to standard USAF modification procedures; they would create an engineering and financial nightmare (ASD/YPPP, 1981:1-1; Morris, 1981; Osborne, 1981). Therefore, the F-16 SPO broke with standard modification management procedures and directed a group of SPO officers to ". . . plan and provide for an orderly approach to accommodate growth into the total weapon system [ASD/YPPP, 1981:1-1]." The SPO received USAF support in this effort, as the Vice Commanders of AFLC, AFSC, and TAC had urged the SPO to develop and implement a master modification plan (MMP) (AFSC, 1979). It is interesting to note that USAF contracted ARINC Research Corporation, who had recently completed an extensive "Aircraft Modification Management Evaluation," to compile the "F-16 Weapon System Master Modification Plan (U)" (ASD/YP, 1980:iii). This plan conformed to the "Styleguide For Preparation of Modification Plans" which was also developed by ARINC as a result of their modification

management research (Gilbertson, 1981). In developing the F-16 MMP, ARINC had an in-depth knowledge of modification management deficiencies that could be corrected.

SPO officers who managed the F-16 improvement effort faced many problems:

1. The F-16 was not originally designed to accommodate MSIP improvements, causing:

   a. improvements to change flight characteristics

   b. the modification effort to be overly complicated. Since subsystems of the aircraft are highly inter-related, most will be affected by modification:

      1. Environmental control systems
      2. Electric power system
      3. Aircraft structural integrity program
      4. Corrosion control program
      5. Aircraft weight summary and maximum gross weight
      6. Volume/Equipment locations
      7. Landing gear
      8. Aircraft performance
      9. Hydraulic system
      10. Accessory drive box
      11. Power plant (ASD/YPPP, 1981:4-2,3).

2. Contractors other than General Dynamics were developing these improvements, causing:

   a. aircraft-improvement interface problems

   b. improvement-improvement interface problems.

3. Not all F-16s will receive the same improvements. Improvements may vary by country and mission, causing difficulty in choosing appropriate improvements.

4. The same improvements were being developed for use on other aircraft besides the F-16, causing suboptimum improvement design relative to the F-16.

5. There was technical uncertainty in improvement development, causing some possibility that certain improvements would never be added.

6. The F-16 was a single seat fighter. Improvements would increase the number of complex system controls in the cockpit causing the pilot to be overtasked in combat, degrading weapon system effectiveness (ASD/YPPP, 1981:1-2; Morris, 1981).

In addition to these major technical problems, there were other obstacles. A major constraint was lack of funding to redesign the F-16, at least in the current budget (Osborne, 1981).

In an effort to deal with these problems, Maj William W. Morris, officer in charge of F-16 improvements, and Mr. D. M. Hancock, Program Manager, F-16 Growth Programs, General Dynamics, worked together closely to formulate a plan that would permit F-16 improvements by reducing improvement cost and at the same time reducing improvement uncertainty. The basis of the plan was to incorporate improvement prerequisites and improvement subsystems into the aircraft on the production line as early as possible so that the F-16 could accommodate future improvements without massive retrofit. The production change began with ECP 0350. The plan was formulated as the F-16 Multinational Staged Improvement Plan (MSIP). It was multinational, since it would accommodate major mission improvements for all countries buying the aircraft. It was staged to reflect efficient weapon system evolution and to manage improvement uncertainty. To understand how MSIP proposed to ac[illegible]lish these tasks, it is instructive to review the three stage[illegible] MSI[illegible]

Stage I begins in November 1981 with aircraft #330, and continues through the production life of the aircraft. The decision to incorporate early structure and wiring provisions for MSIP improvements was made with the greatest amount of uncertainty in Stage I, since this stage is furthest (removed in time) from incorporating the ultimate improvements. MSIP managers attempted to solve this uncertainty in Stage I by pre-

planning for flexibility. Prerequisites chosen to reduce the cost of modification had to be applicable to the widest range of possible improvements. Also, since no extra funding was available, prerequisites had to have a very high reward/cost ratio to justify freeing dollars from other funds. Stage I prerequisites are very basic, adding no extra performance capability to the aircraft, but making it possible to add improvements without massive retrofitting. For example, to add AMRAAM (which is a highly likely improvement) without Stage I prerequisites, aircraft wings would need to be removed from the aircraft and completely torn apart. Five to seven wing spars would be replaced, the slats and flaps removed, and the wing reskinned. The cost of this retrofit for one wing is more than the entire cost of Stage I prerequisites for the entire aircraft, which is comparatively low, adding about $130,000 to each aircraft's pricetag for an increase of only 1.25% of total aircraft cost (Morris, 1981).

Stage I prerequisites are primarily defined by ECP 0350:

1. Wing structure and wiring provisions for beyond visual range air-to-air missiles.

2. Engine inlet structure and wiring provisions for various electro-optical and target acquisition pod systems.

3. Cockpit structure and wiring provisions for a wide field of view raster head up display, multifunction display set, data transfer unit and Up Front Communications/Navigation/Identification.

4. Wiring provisions for an expanded capacity fire control computer, advanced weapons central interface unit, radar altimeter.

5. Early structure and wiring provisions for internal ECM systems.

6. Increased capacity environmental control system (ASD/YPPP, 1981:1-1,2).

Stage I is further defined by ECP 0425, which increases the size of the horizontal tail for increased maneuverability when pods or other armament are attached to the aircraft.

As explained above, Stage I prerequisites are for structure and wiring, since these are the most costly to retrofit. Mr. Charles A. Gifford, author of MIL-STD-1553, Multiplex Applications Handbook, stated that the cost to retrofit one wire is about $1000 per aircraft bulkhead, and a typical wiring retrofit passes through 8 bulkheads (Gifford, 1981). Once the structure and wiring is in place, future improvements can be attached with the addition of supporting subsystems (Morris, 1981). These subsystems are added in Stage II.

Stage II builds upon Stage I by adding subsystems that support final MSIP improvements. Stage II begins in July 1984, but the prerequisites of Stage I will continue to be added along with these subsystems. Since Stage II is closer in time to the final improvements, there is more certainty towards those improvements. Also, these subsystems will contribute to improve aircraft capability in themselves, ensuring ". . . changes necessary to maintain single pilot operability in high task/threat situations through up front controls and displays [ASD/YPPP, 1981:1-2]." Stage II subsystem changes are:

1. Increased capacity Fire Control Computer (FCC).

2. Advanced Central Interface Unit (ACIU) for multiple weapons handling and launch.

3. Multifunction Display set (MFD) and software programmable display generator to replace the current stores control panel and radar symbol generator.

4. Programmable Signal Processor (PSP) for improving the APG-66 radar.

5. Dual Mode Transmitter (DMT) for improving the APG-66 radar.

6. Radar Altimeter (RA).

7. Data Transfer Unit (DTU).

8. Up Front Communications/Navigation/Identification (UFCNI).

9. Wide angle heads up display (HUD) for LANTIRN.

10. Improved Environmental Cooling System (ECS) turbine assembly to provide added cooling capacity (ASD/YPPP, 1981:2-1).

The relationship of these subsystems to potential improvements is depicted in Figure 9, "F-16 Improvement-Subsystem Relationships". As depicted in Figure 9, many subsystems are prerequisites for more than one improvement. Pre-planning these supporting subsystems achieves additional flexibility to manage improvement uncertainty, by increasing the possibility that the subsystem incorporated will be used. Usually, on-board subsystems require added capacity as they support more improvements. To handle added capacity, all of these subsystems are designed as if the F-16 were to add all MSIP improvements. Further, there is little extra cost to increase the capability of these subsystems once they have been added to the aircraft. As another example, Figure 10, "F-16 Environmental Cooling System," illustrates the incremental cooling capacity needed as more improvements are added. The ECS was designed to increase cooling capacity easily, to accommodate all MSIP improvements.

Like Stage I, Stage II will continue for the production life of the aircraft. Aircraft delivered between November 1981 and July 1984, without Stage II subsystems, will need to be retrofitted for these subsystems. However, the cost of retrofit will not be high since prerequisites for these subsystems were included in Stage I.

	FCC	ACIU	MFD	PSP	DMT	RA	DTU	UFCNI	HUD	ECS
AMRAAM										
- Launch and Leave		X								
- Launch and Update	X	X		X						
- Multitarget	X	X		X						
- Full Envelope	X	X		X	X					X
LANTIRN										
- Night Navigation FLIR									X	
- Low Level/Day						X			X	
- Low Level/Night			X			X		X	X	
- Radar TF			X	X		X				
- Rapid Fire	X	X	X	X						
- Target Acquisition	X	X	X	X						
JTIDS	X		X				X			X
GPS	X						X			
ASPJ	X						X			X

Figure 9

F-16 Improvement-Subsystem Relationships
(Morris, 1981)

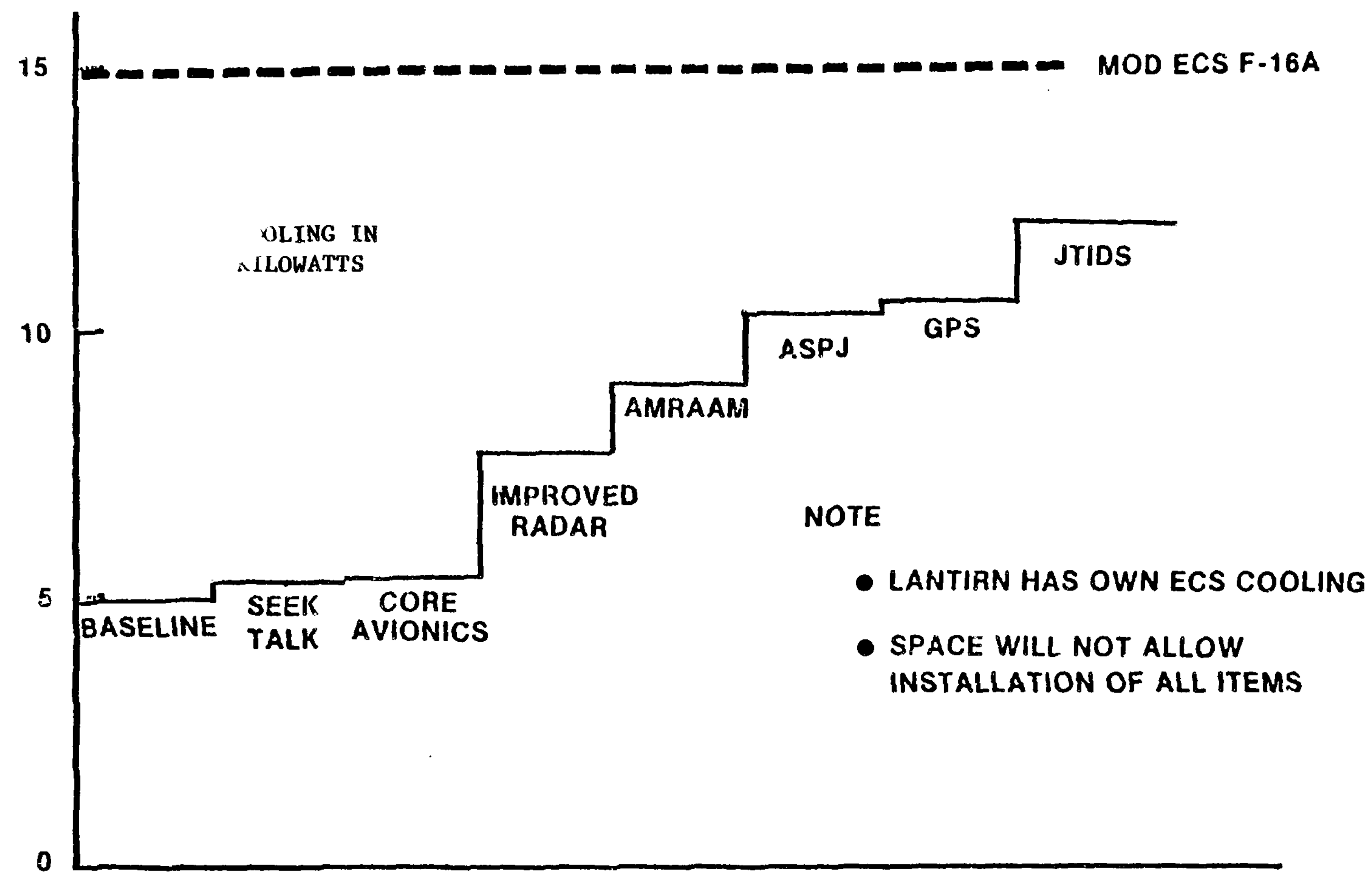

Figure 10

F-16 Environmental Cooling System
(Morris, 1981)

Stage III begins as actual growth system improvements are incorporated on the production line to meet new mission requirements, i.e., AMRAAM, GPS, LANTIRN, etc. Operational aircraft can be improved usually with only a few changes in switches and plugs (Morris, 1981).

Managing Improvement Uncertainty

Threat, Technology, and Mission Requirements Forecasts. F-16 improvements were selected by TAC and NATO based upon the Warsaw Pact threat, future technology developments, and potential F-16 mission requirements in the European Theatre. TAC urged that these improvements should be incorporated into the F-16, which was the task of the F-16 SPO. Whereas the SPO itself did not use forecasts to select specific improvements; they did use technology forecasts to schedule improvements into an orderly and efficient plan - the MSIP.

Risk of Improvement Cancellation. The risk of improvement cancellation varies from improvement to improvement. The AMRAAM is almost certain to be incorporated into the F-16, whereas JTIDS may not be incorporated (Morris, 1981). Risk of improvement cancellation was not a decision variable as the SPO formulated MSIP. TAC dictated F-16 improvements and the SPO proceeded as if these improvements would be incorporated. As noted in the F-16 introduction, the F-16 could not accommodate future improvements in its initial configuration. Therefore the SPO added prerequisites and subsystems into the aircraft, via MSIP I and MSIP II, that would make improvements more easily accommodated.

The SPO selected for Stage I those prerequisites that offered the most substantial savings for improvement, and were relatively

inexpensive i.e. with a high reward/cost comparison. If the targeted improvements are never incorporated, little will be lost. However, Stage I prerequisites offer tremendous flexibility because they are so basic to any future F-16 improvement effort. General Alton Slay briefed the ADPA P^3I Seminar & Workshops that after 10 years of service the F-16 will likely have more derivatives than the F-4, which has 19 (ADPA, 1981). Thus, there is little chance that Stage I prerequisites will not contribute towards reducing MSIP improvement costs, even if some planned improvements are cancelled, because there is a great chance that other improvements will use these same prerequisites. In this respect, prerequisites that are very basic to future improvements have an inherent flexibility that allows for a range of improvement candidates, and reduces improvement uncertainty.

Stage II subsystems will be incorporated nearer to the time when actual improvements are fully developed and funded for modification, therefore, by MSIP design, there is a much higher degree of certainty that Stage II subsystems will be useful. Also, since many subsystems support more than one improvement, there is little chance that a subsystem by itself will never be used.

Reward/Cost Comparison of Pre-Planning

For Stage I prerequisites, the reward/cost comparison is very high. The F-16 has many highly inter-dependent subsystems, more than many aircraft, due to a sophisticated central data computer that integrates inputs from many aircraft subsystems. Also, fly-by-wire flight controls are integrated into the electrical system. Changes to one aircraft subsystem will necessarily affect many other subsystems,

causing modification costs to rise. Also, by design, F-16 subsystems are optimized for flight performance, and except for modular components and extra space, provisions for aircraft subsystem improvement and growth were initially neglected. Thus, prerequisites added to the aircraft have the potential to significantly reduce improvement costs. Since Stage I prerequisites are very low cost, the overall reward/cost ratio is very high, which aids in reducing improvement uncertainty.

Stage II subsystems are also necessary for future improvements, but unlike Stage I prerequisites, Stage II subsystems improve the immediate capability of the aircraft. While their reward/cost comparison is lower than Stage I prerequisites, they will contribute to increase aircraft performance, especially in organizing cockpit duties for system operation in high task/threat environments. Thus, Stage II prerequisites have some inherent value other than reducing improvement costs.

Other Factors. Major Morris emphasized that an important thought process occurred in formulating MSIP. As improvements were conceptually added to the F-16 one-by-one, General Dynamics engineers and SPO managers had to continually question what aircraft interfaces were affected: in more simple terms "What could go wrong next [Morris, 1981]?" Anticipating problems as each improvement was added was an on-going effort behind MSIP. In this way, subsystem interaction problems were recognized, and early in F-16 production basic prerequisites were added to the aircraft to provide for later changes that would alleviate subsystem interaction problems. Specifically, the "F-16 Weapon System Master Modification Plan (U)" identified critical subsystem interactions for each potential improvement. As an example, addition of Global Positioning System (GPS) will

affect F-16 aircraft weight, power, environmental control, automated data processing, and internal equipment space available as noted in Figure 11, "Tentative Modification Impact Summary." Also, GPS will affect the aircraft electrical system, software, and TACAN as noted in Figure 12, "Modification Description Data." This figure also lists "Other Critical Program Links," "Program Elements," and "Other Modifications" necessary for installation of GPS. With subsystem interactions identified, it is relatively easy for engineers to pre-plan for GPS by incorporating prerequisites and adding/changing subsystems to accommodate GPS within the orderly schedule for aircraft improvement that is defined by MSIP. The F-16 SPO worked closely with General Dynamics engineers to identify subsystem interaction and select prerequisites and subsystems to give the F-16 the potential for future growth. This effort is consistent with the goal of a long program life.

As an additional finding it is interesting to note that although General Dynamics did not initially design the F-16 for MSIP improvements, they did design major components such as wings, fuselage, etc, with modularity. General Dynamics has used this modular capability to design a delta-wing F-16XL with an improved version of the Pratt and Whitney F-100 engine. The F-16XL will carry,

> . . . twice the bomb load of the F-16, fly substantially increased radii, in both air-to-air and air-to-ground missions, be more maneuverable, and require much shorter take-off and landing distances. The plane's fuselage is stretched 54 inches, increasing internal fuel capacity by 82% and adding 40 cubic feet of volume for new avionics and sensors ["USAF to Fund F-16XL Development, Plus F-15E," 1981:16].

Thus, General Dynamics used its own resources to develop the F-16XL, as an unsolicited proposal, that (if accepted) would increase the F-16 production life by producing an F-16 derivative that is low cost because

Title	Net Impact on Key Factors [1]					Notes
	Weight	Power	Environmental Control	Automated Data Processing [2]	Internal Equipment Space Available	
Low Altitude Navigation and Targeting Infrared for Night (LANTIRN)	17 lb. Group A 535 lb Group B 2.3% FWD C.G.[8]	9.0kVA	N/A	(300-1800) words, (3-7%) duty cycle FCC (100-200) words (SMS/CIU)	N/A	3,4,9
Airborne Self Protection Jammer (ASPJ)	397 lb. total	7.19kVA	6.31kW	(20-100) words FCC 0.8% to DMU utilization	4.75 Cu Ft including shock mount and sway space	
Global Positioning System (GPS)	76 lb. total 0.9% FWD C.G.	0.24kVA	0.18kW	(3000-3500) words 6% duty cycle FCC	0.65 Cu Ft Box Volume	5,10
Multiple Stores Ejector Rack (MSER)	N/A	Not Available	Not Available	(50-250) words FCC (50-100) words SMS/CIU	N/A	6
Advanced Medium Range Air to Air Missile (AMRAAM)	84 lb. total not including pylons or launchers 0.4% FWD C.G.	0.2kVA	0.2kW	(1600-4100) words, (3-5%) duty cycle FCC (3300-5800) words SMS/CIU	0.65 Cu Ft Box Volume	7,11
SEEK TALK	68 lb. total 0.8% FWD C.G.	0.12kVA	0.10kW	N/A	0.45 Cu Ft Box Volume	

Figure 11

Tentative MSIP Modification Impact Summary
(General Dynamics, 1980:Table 6-5)

Other Critical Program Links	Program Elements	Other Modifications
Prerequisite for this modification: This modification prerequisite for: Required concurrent with this modification:	64778F (NAVSTAR GPS) 35164F (NAVSTAR GPS User Equipment) 35165F (NAVSTAR GPS Space and Control Segments)	ECP 0350[2]

Other Systems or LRUs Affected by this Modification	Electrical Interface	Mechanical Interface	Relocation	Software	Other	OPR For System Interfaced
Fire Control Computer	X			X		ASD/YPEA
Fire Control Navigation Panel	X					ASD/YPEA
ARN-118 TACAN					X[3]	ASD/YPEA OO-ALC/MMA
Support Equipment - TBD						

Remarks: [1]Total R&D GPS user funding reflected in AFSC FY 82 POM is shown.
[2]Some Group A provisions are planned for incorporation under ECP 0350.
[3]Installation of GPS may result in removal of TACAN.
[4]GPS program is currently undergoing major restructuring which could significantly change the funding profile and delay full system implementation.

Figure 12

MSIP Modification Description Data
(General Dynamics, 1980:C-24)

a P^3I strategy was used.

Another factor that reduced improvement uncertainty was the placement of General Dynamics F-16 engineers into the plants of improvement developers. This effort again was implemented to anticipate problems. A slight change in an improvement could have a negative affect upon F-16 performance or other F-16 improvements. Thus it was important to improvement development that an F-16 expert would assess any improvement design changes.

Summary

The F-16 SPO did not use forecasts of the future threat, technology, and mission requirements to select F-16 improvements; TAC led the SPO to plan for these improvements. The SPO used forecasts of future technology to formulate an orderly and efficient plan for improvement, and also to manage improvement uncertainty; this plan is the F-16 MSIP. Due to the sophisticated nature of the F-16 and MSIP improvements, the fact that different countries will purchase different improvements, and because different contractors are developing these improvements, there is a high degree of uncertainty in the improvement effort. The SPO managed that uncertainty by adding only Stage I prerequisites when uncertainty was at its highest. These prerequisites were applicable to a wide range of potential improvements and had a high reward/cost comparison. The SPO then added subsystems later that support improvements and contribute to overall system capability, when improvement uncertainty was lower. Other factors, such as the conscious effort to continually assess subsystem interaction as improvements are added increased the efficiency of pre-planning and reduced improvement uncertainty.

Similarly, the effort of General Dynamics to control improvement development by different contractors helped to improve engineering efficiency and reduce improvement uncertainty.

The F-16 MSIP was an effort to manage long term improvement uncertainty and used much of the same logic used by Boeing to manage long term uncertainty in their programs. More will be said about these parallel efforts in the conclusion of the thesis.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Conclusions on The Nature and Role of P^3I

Research findings of "The Nature of P^3I" were presented apart from findings of "The Role of P^3I" and "Managing Improvement Uncertainty," which were each presented independently for each P^3I program example. However, these findings overlap and support each other, and considered as a whole lead to general conclusions and recommendations. The first set of conclusions concern the nature and role of P^3I as P^3I has evolved from simple applications to become a discipline in itself.

Conclusion One: P^3I has already been applied, in varying degrees, to Commercial and Military Programs. These applications were not always integrated into a formal plan but do carry many of the seeds of a P^3I approach.

Discussion: It is difficult to document exactly when pre-planning was first used, in part, because P^3I embodies, largely, applied common sense (Lyon, 1981b). Consider the simple example of a manufacturer who plans to build a new production plant with three production lines. Three lines will satisfy present market demand for his product, and will ensure optimum production capacity. However, the manufacturer is confident that some day in the future market demand for his product will increase, and eventually he must add a fourth production line. To design the new plant with three lines will provide optimum production capacity now; however, later addition of the fourth line will force the plant layout

to be reorganized and could cause excessive plant down-time and expense.

As a cost-efficient alternative, the manufacturer can pre-plan the fourth line into his plant design and avoid large amounts of future plant down-time and expense. For example, the plant floor plan could be laid-out to naturally accommodate the fourth line: the floor plan can be pre-planned to easily route production inputs to the fourth line, and outputs from the fourth line can be pre-planned to easily merge with outputs from other lines. Provisions in the plant architecture for electrical wiring and plumbing to support the fourth line could be included. Since these prerequisites would be built into the design they would cause only a slight increase in plant cost, compared with adding these later, after the plant was built.

The benefits of pre-planning the fourth line into the plant design are obvious. A plant with only three lines can be built with less cost and in less time than a plant with four lines. Three lines will provide optimum production capacity. Also, by including basic building prerequisites for the fourth line, at little extra cost, the plant can easily accommodate the fourth line when product demand has increased sufficiently to warrant its use; a major plant reorganization is not required.

This simple example illustrates a manufacturing effort to reduce costs and increase responsiveness to market demand, and requires little, if any, in-depth system analysis. In this way, the P^3I concept has been used often in design applications. However, pre-planning a very complex system necessitates a more rigorous system analysis.

Conclusion Two: Complex P^3I Applications Require a Structured Program Architecture

Discussion: The greatest engineering impediment to pre-planning change in a complex system has been the inability to manage the multitude of complex subsystem interactions that result when one subsystem is changed. This problem was first overcome in the field of computer software design. As the computer industry began to enjoy the benefits of advances in circuitry, making computers far more capable to handle very complex and involved calculations, computer programs themselves became very complex and involved. This caused problems because there was no standard methodology for program design. Each programmer used his own techniques to formulate a complex program. Without a programming methodology, some programs were written very inefficiently, using as much as ten times more computational time and memory space than actually needed (Weinberg, 1979:27). In addition, the only person normally capable of understanding and debugging a complex program was the original programmer himself. Debugging was an arduous and time-consuming task, because a minor change in one program sub-element would force major changes in other sub-elements, often invalidating the entire program. Faced with these obstacles, computer analysts developed a methodology for software program design known as structured programming, that would make programs (1) more understandable, flexible, and verifiable, (2) more economical to run because of better organization, and (3) more error free and easy to correct (Ralston, 1976:1367).

Structured programming is an architectural concept that organizes a software program into conceptual layers, beginning with the most

abstract program objective, then progressing downward through layers of more and more specific detail. Each layer can further be separated into independent modules by a chosen criteria, often related to a specific function. Each module may communicate with modules of lessor detail, but modules in the same layer do not communicate directly with one another (Figure 13).

Structured programming is a "top down" architecture. Broad objectives are formulated at the top and then translated through layers of progressively more detail. Modules in each layer exhibit independence; minor changes to one module have no direct impact on other modules in the same layer. This philosophy, which is really no more than a form of programming discipline imposed upon software designers, minimizes the daisy-chain effect often inherent in changing a lower level module. Although structured programming is a simple concept, its actual application to software design has profoundly increased the efficiency of software programs (Weinberg, 1979:28). In particular, once modules are

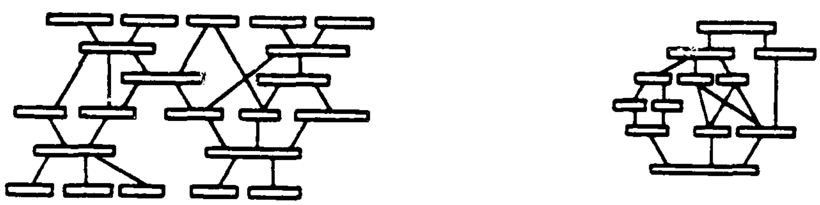

Figure 13

Examples of Layers and Modules in a
Structured Program Architecture
(Ralston, 1976:1288)

defined, they can be designed and debugged independently, and then assembled easily to construct the entire software program (Ralston, 1967:1287).

The computer industry has been fiercely competitive, seeking a wide variety of applications as a source of profit. Once a complex program was written, it became cost-effective for a company to make minor changes to that program to make it fit related applications, rather than tailor-make a new software program for each new application. As an example, in 1969, Shared Medical Systems Corporation, now a multimillion dollar enterprise, started business by purchasing IBM general accounting software programs and then modifying those programs to fit the needs of hospital accounting ("The Growth Industry's Growth Industry," 1981:144). Faced with requirements to modify programs for a variety of future applications, programmers began to pre-plan modules to easily accommodate future programs. In essence, with a small extra effort in initial module design, programmers were saving themselves a great deal of extra effort when the program was later changed to adapt to other applications. This methodology was not formally documented, perhaps since pre-planned module change was so obviously a common sense approach to module design (Lyon, 1981b).

ADPA originally labeled P^3I as "Modular Evolutionary Development" (MED), connoting the evolution of modules defined in the context of structured programming ("Modular Evolutionary Development Proposed," 1980:52). However, ADPA realized that MED focused on the concept of modular design, which most people translated to hardware directly as "black-box" modules (Aquilano, 1977:89,90). Actually, hardware modules may be the end product of a structured program architecture, but rarely

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is this the case. For example, on a functional level, aircraft navigation can use parts of the inertial navigation unit, scanning radar, doppler radar, central computer and cockpit displays. Only parts of these individual black-boxes are dedicated to the navigation function (the radar, for instance, is also used for attack and enemy detection). Traditional modular design does not recognize the future requirement for new functions, many of which might be partially served through existing hardware. Complicating this situation is the current Air Force thrust towards commonality. System component hardware and software, with or without P^3I provisions, is being pushed towards common design to serve diverse weapon systems. A doppler radar, for instance, should serve cargo aircraft as well as bombers. All of these considerations have been wrapped up in the evolving definition of MED. Accordingly, ADPA chose to drop the term MED in favor of a less encumbered term which they coined as P^3I (Lyon, 1981b).

The transition from simple to complex P^3I applications is made feasible by the structured programming concept. Once a system is defined by an architecture of independent modules, these modules are, in theory, designed to efficiently accommodate future improvements without disturbing other modules. However, for some complex systems, such as a military aircraft, the task of defining individual modules may be much more difficult, since many subsystems are highly dependent. In this case, one must anticipate module interaction, designing modules that will minimize the affects of interaction, or easily adjust to changes in interaction. Here CAD/CAM plays a vital role. CAD/CAM can simulate potential modifications and then identify the resultant affects on dependent subsystems.

Thus, using computer simulations, subsystems can be identified and then designed with the necessary growth potential to accommodate changes. Inherent in this process is the ability to recognize performance and subsystem tradeoffs. Change in one subsystem may adversely affect the performance of other subsystems, forcing tradeoffs. The complexities involved in subsystem interaction and tradeoffs can be conceptually approached, once they are identified, using techniques of multivariate optimization. These computations are lengthy and involved. Further, the subsequent chain of interactions between interactions (i.e. 2nd and 3rd order interactions) quickly evolve to the complexity of high order differential equations. Thus, actual solutions, even when constrained, can only be arrived at by computer (Ashley, 1981).

Conclusion Three: The sum of all P^3I application to complex systems is, de facto, evolving a discipline and structure to the P^3I process.

Discussion: The P^3I Seminar defined P^3I in three parts:

> P^3I is a systematic and orderly acquisition strategy beginning at the systems concept phase to facilitate evolutionary cost effective upgrading of a system throughout the life cycle to enhance readiness, availability, and capability.
>
> The modular baseline configuration design shall permit growth to meet the changing threat and/or to take advantage of significant technological and/or operational opportunities through future modifications or product improvements at appropriate time intervals.
>
> The baseline technological risk will be minimized and provide early availability by utilizing well known and established technology to the maximum extent feasible, limiting advanced technology to the sub-system(s) offering substantial operational or cost benefits [Lyon, 1981a:22].

The first two parts of this definition were explained in the simple manufacturing plant and the structured programming examples. The third part is a derivative of the first two parts. In most system

acquisitions engineers have been required to develop a system that incorporated the newest frontiers of technology. The services have reasoned that using the newest technology would delay system obsolescence and improve the U.S./Soviet technological balance. However, with this approach, cost overruns were frequent, the acquisition schedule was often delayed, and the final system had high failure rates due to its complexity. These problems were directly attributable to the fact that sophisticated technology requires lengthy development and testing to properly integrate into a weapon system. In contrast, a P^3I system design, with a schedule of improvements, does not need as many new frontiers of technology. The system can be built with current off-the-shelf technology to meet short range mission requirements, and then gradually improved in response to changing threat, technology, and mission requirements throughout its lifetime. As a result, the initial system will cost less, can be built more quickly and with less risk, and will be more reliable when fielded. Improvements can begin to be developed early, even concurrently with system development, then installed on a trial basis in a few production systems for testing.

In summary the thesis of P^3I is that improvements can be incorporated more quickly and efficiently when planned into an initial system design. Further, the average level of technology will be higher, throughout the system lifetime, if the system is developed with off-the-shelf technology and then modified with an orderly schedule of planned improvements; rather than, as is now the case, developed with advanced technology and then modified to correct deficiencies.

The P^3I process could be generally described as depicted in

Figure 14, "The P^3I Process". The process begins when current, as well as forecasted, threat, technology, and mission requirements are evaluated to select a system (1). The P^3I criteria for system selection includes the ease with which a system can respond to changing states of threat, technology, and mission requirements throughout its lifetime, not just how well the system meets initial fielding requirements. Once a system is chosen, a "System Requirements Evaluation" (2) selects initial system requirements, valid for the time when the system is fielded, plans a schedule of potential improvements, and selects prerequisites that will support that plan and also reduce long range improvement uncertainty (this selection process is covered in more detail in the next section). These outputs are inputs to a "Structured Programming Analysis" (3) that defines system requirements as a system design characterized by independent modules. If modules are not independent, their interactions must be considered in system design to allow for module change. This design, which includes improvement prerequisites, is the basis for system development and production. As the system is being developed, produced, deployed and used, updated forecasts of threat, technology, and mission requirements serve as inputs for continued System Requirements Evaluations (2), (4), and (5), resulting in continued system improvement, revised schedules of improvements, and new prerequisites that should be added to support the revised schedule of improvements.

It is possible to insert a system into the P^3I process at any point in its lifetime, even if the system did not begin with an original P^3I plan, because prerequisites can be added during production, modification, or scheduled maintenance; the F-16 MSIP program adds prerequisites

(1) Current and Forecasted TT&MR* → System Selection

↓

1. System i.e., aircraft

↓

(2) Current and Forecasted TT&MR → System Requirements Evaluation

↓

1. Initial System Requirements
2. Schedule of Potential Improvements
3. Prerequisites for Improvement

↓

(3) Structured Programming Analysis

↓

1. Initial System Design → System Development

↓

(4) Updated Forecasts → System Requirement Evaluation

↓

1. 1st Improvements
2. Revised Schedule of Improvements
3. New Prerequisites

→ Improve System, Add Prerequisites

↓

(5) Updated Forecasts → System Requirement Evaluation

↓

1. 2nd Improvements
2. Revised Schedule of Improvements
3. New Prerequisites

→ Improve System, Add Prerequisites

↓

etc   etc

*Threat, Technology, and Mission Requirements

Figure 14

The P^3I Process

in production beginning with aircraft #330. Further, right along with the development of the system can be development of individual improvements to help reduce improvement uncertainty.

Although the P^3I process looks specific and concrete conceptually, there is always a great amount of uncertainty in forecasts. Uncertainty can precipitate planning for the wrong improvements, or result in cancellation of selected improvements. The findings of the three P^3I program examples, and conclusions drawn from them, illustrate how this uncertainty can be managed.

Conclusions on Managing Improvement Uncertainty

The three program examples chosen to investigate long range improvement planning had used the P^3I strategy before ADPA had coined the phrase or investigated P^3I implementation concerns. These programs chose to pre-plan as an economic necessity because the cost of un-planned improvements could no longer be borne. Thus, P^3I was operating in these programs without knowledge of ADPA's work. Even though these programs are quite different i.e., a commercial aircraft, a missile, and a military aircraft, they share common characteristics in the methods used to manage long range improvement uncertainty.

Conclusion Four: Threat, technology, and mission requirements forecasts are the basic means to manage improvement uncertainty.

Discussion: The three program examples illustrate that the choice of improvement candidates is dependent upon forecasts of threat, technology, and mission requirements. The three examples showed a range in the use of these forecasts, yet all were able to use forecasts to pre-plan

effectively. For the 727, Boeing has taken the initiative to continuously update customer and economic forecasts for a continued P^3I effort. For the ALCM, forecasts were limited due to their sensitive nature, but general missions were anticipated. For the F-16, the SPO planned not from threat forecasts, but from a known, validated threat and a technology master plan of available options. The fact that forecasts of threat and mission requirements were limited in ALCM and the F-16 did not negate pre-planning, but did affect the detail of out-year requirement definition. Technology forecasts were available in all three programs, and a key input for pre-planning. Boeing was able to actually influence the outcome of its technology forecasts for the 727 and ALCM as company labs and design engineers worked closely to develop selected improvements. The F-16 SPO used technology forecasts i.e., the estimated dates when MSIP improvements would be fully operational, to formulate an efficient schedule of improvements and manage uncertainty in stages. Of the three examples, ALCM stands out for its resourceful forecasting. Boeing did not have actual threat and mission requirements forecasts. Because Boeing had a wealth of experience in forecasting and pre-planning, however, they were able to use their own estimates of likely ALCM scenarios in place of DOD forecasts. Thus, with the odds stacked against Boeing, both in inadequate DOD forecasting and also in the highly constrained potential to include P^3I prerequisites, Boeing still was able to design ALCM with enough flexibility to anticipate improvements and reduce improvement costs. In essence, this example shows that P^3I is possible even in the most unlikely of situations if a commercial enterprise really works to increase the likelihood of making a greater profit.

Conclusion Five: Appropriate use of P^3I prerequisites in initial design can actually serve to decrease improvement uncertainty.

Discussion: The findings of the three P^3I program examples, show that after forecasting, the resultant choice of prerequisites can significantly improve the potential to reduce improvement costs and manage uncertainty. In the worst case, the choice of a prerequisite could be wrong and a prerequisite never used, resulting in a complete waste of pre-planning. The program examples approached this undesirable situation in two ways: by increasing the likelihood that a prerequisite will be used, and/or holding down the costs of pre-planning. The likelihood that a prerequisite will be used is dependent upon the probability that any derived improvement will be incorporated, and also the number of such end improvements. A hypothetical structured program example, which in many ways resembles the F-16 MSIP, is shown in Figure 14, "Example of Prerequisite Flexibility".

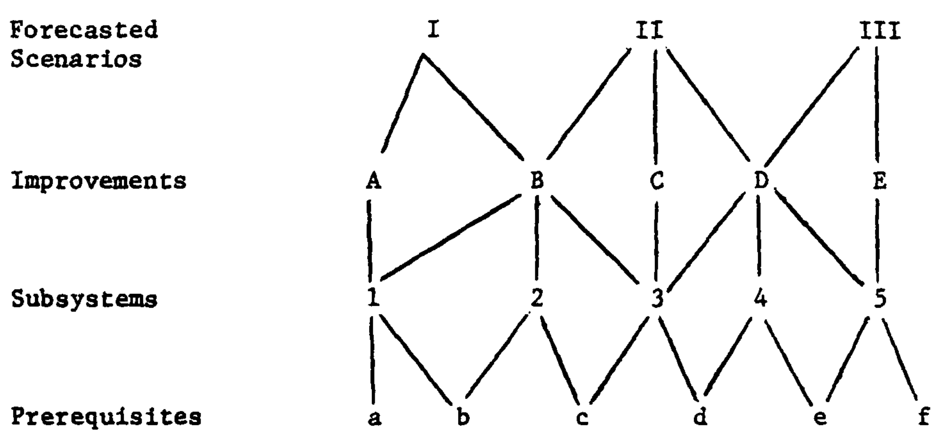


Figure 15

Example of Prerequisite Flexibility

In this example, each scenario requires one or more major improvements to attain it. Each major improvement, in turn, affects a given number of subsystems. If one were to design with growth provisions, certain initial P^3I prerequisites would need to be added to the system even though they didn't enhance initial system performance.

One could evaluate the choice of prerequisites as follows:

Scenario I Prerequisites: a, b, c, d

Scenario II Prerequisites: a, b, c, d, e, f

Scenario III Prerequisites: c, d, e, f

Since prerequisites c and d are common to all scenarios, they have the most flexibility and are more certain to reduce improvement costs regardless of which scenario actually occurs in the future. Next, prerequsites a, b, e, and f are common to more than one scenario, and are also candidates for selection. This example can be refined if each scenario is assigned a probability. By not assigning a probability to the above scenarios, one tacitly assumes that each scenario is equally likely and prerequisites from a to f have a probability of being used of 2/3, 2/3, 1, 1, 2/3, and 2/3. Assigning different probabilities to these scenarios changes their prerequisite weightings. The prerequisite weighting was found usually to be insensitive to small changes in scenario probability. Since future scenarios are somewhat uncertain, this trait is to the advantage of planners. However, if one scenario is significantly more probable than others, it is important that scenarios reflect the proper probability. For example, if the probabilities for Scenarios I, II, and III were changed from 0.33 each to 0.8, 0.1, and 0.1, respectively, then the weights of the prerequisites a to f would

change to 0.9, 0.9, 1.0, 1.0, 0.2, and 0.2. As would be expected, since Scenarios II and III are far less probable, weights of prerequisites e and f have dropped from .67 to 0.2. This model could be developed in equation form in which case coefficients would represent sensitivities, assuming the model is linear.

While conceptually sound, one might ask if prerequisites and potential improvements are actually so closely linked in practice. It is, indeed, the nature of complex systems to have highly related subsystems. Referring to Figure 9, "F-16 Improvement-Subsystem Relationships," one notes a very high degree of interdependence between F-16 MSIP improvements, such as AMRAAM, LANTIRN, JTIDS, GPS, and ASPJ, and their ten related subsystems. If structural and wiring prerequisites were also included, one would see this interdependence compound several times over.

In addition to the criterion for prerequisite flexibility, the reward/cost comparison offers yet another means to manage improvement uncertainty. Under this approach, a necessary condition for a prerequisite to be included in an initial system design is that the reward/cost comparison be greater than one. A program manager might thus include some prerequisites in an initial system design if their reward/cost comparisons are very high, even if the probability they will be used is low, because they offer so great a potential savings in improvement costs. A second consideration in this decision might include Boeing's observation that the longer the program life, the more likely prerequisites will contribute to reduce improvement cost.

As part of the System Requirement Evaluation within "The P^3I

Process" depicted in Figure 14, a separate prerequisite evaluation could be done to select prerequisites with the greatest potential to reduce improvement costs and keep pre-planning costs low. The major factors in this evaluation would be:

1. The probability given to a future scenario, which is transferred to prerequisite weights.

2. The flexibility of prerequisites, which also impacts prerequisite weights.

3. The reward/cost comparison.

One could simply multiply prerequisite weight times reward/cost comparison, and then rank these values, choosing those with the highest values for actual incorporation into the system design. The decision model could be simple or sophisticated depending on the users wishes and analytical ability. The interviewed program managers who actually selected prerequisites did not use such a model, but combined these factors subjectively based, in part, on their past experience.

<u>Conclusion Six: Long range improvement uncertainty is manageable and not fatal to P^{3}I.</u>

<u>Discussion</u>: The three P^{3}I program examples offer a variety of systems and improvement scenarios, yet each example was able to manage long range uncertainty and effectively pre-plan for improvement. Further, these examples, though different, used the same methods to pre-plan. The F-16 MSIP had no knowledge of Boeing's P^{3}I process, yet SPO officers working with General Dynamics included prerequisites in the F-16 based upon the prerequisite flexibility and reward/cost comparison, just as Boeing did. The major difference between the F-16 MSIP and Boeing is that Boeing's P^{3}I process is a continuing process, that begins in the

conceptual phase of a program and continues throughout the program life. The F-16 MSIP improvements was a one time effort accomplished in the production phase. The F-16 SPO can, however, continue to receive updates of TAC's plans for improvements, so that those newer improvements can also be pre-planned. Failure to recognize that pre-planning can reduce the improvement cost is a greater impediment to P^3I than long range uncertainty itself.

General Conclusions

Conclusion Seven: P^3I is a strategy which improves a contractors probability of making a profit. It is not a necessary requirement that P^3I be subsidized by the government.

Discussion: The interest in formalizing and recommending P^3I to the DOD originated in industry - and for a good reason. Industry has committed large investments in DOD contracts, only to have many contracts reduced or cancelled, forcing significant losses. As a result, industry has reduced its commitment to defense programs. If P^3I can give defense programs greater flexibility, so that a program can be easily improved to meet changing defense needs, then there is more likelihood that such a program will have a long life, providing greater program stability and a greater return on the contractor's investment. The Boeing 727, the ALCM, and the F-16XL were designed with prerequisites for growth. Each company invested its own resources, without government support, to pre-plan and develop improvements in these systems that would increase the potential for a long production life. This investment was motivated by the expectation that the increased ability to rapidly and efficiently improve their products would give them an advantage over competitors

in the market place for their products. Since these companies had their future profitability at stake, they made a conscious effort to pre-plan and put the odds for success in their favor. Given the past success of commercial P^3I programs, if P^3I can help add stability to DOD programs, industry should support the DOD in P^3I efforts, even at some initial cost to them.

Conclusion Eight: Even more important than government development and control of a sophisticated P^3I system is the requirement for government to not inhibit P^3I use by contractors. Several government perspectives and policies currently inhibit P^3I.

Discussion: The current DOD acquisition system is based upon short range planning. Reasons are many and varied, but one major reason lies in the uncertainty, magnified in the military milieu, inherent in long range planning. The DOD must answer to Congress and the American people for their decisions, and have accordingly based new programs on short range planning, where a current threat can be validated and decisions more easily quantified and justified. Further, the DOD budget is saturated with funding requests for programs that are based upon short range goals, yet not all these programs will be funded. Therefore, there is an inherent probability that programs based upon long range threat projections have little chance of approval.

DOD acquisition regulations reinforce short range planning. In his 19 June 1981 Memorandum to the Service Secretaries in charge of Research and Development, Under Secretary of Defense for Research and Development, Dr. Richard DeLauer stated,

> . . . OMB Circular A-109 and DODD 5000.1/DODI 5000.2 state that Defense system acquisition programs must be based upon a "validated threat". Many OSD and Service officials interpret the term "validated" to mean a threat that has been proven and documented [DeLauer, 1981].

Dr. DeLauer is particularly worried about electronic warfare (EW) programs, which are being penalized by short range planning more than other programs because of the rapid growth of new electronic developments. Dr. DeLauer cited a recent study by a government/industry EW Acquisition Process Review Committee concluding that an average EW program spends 10 years in development before fielding. Since the conceptual acquisition phase does not begin until the threat has been identified and validated, "In most cases, we are developing changes to those (EW) systems to respond to new threats even while the initial design is still undergoing repetitive testing against older threats [DeLauer, 1981]." The government/ industry EW Committee concluded that,

> . . . The term "validated threat" should be interpreted to mean a project threat, approved by the DIA, of estimated future enemy capabilities based upon intelligence, extrapolating of existing enemy weapon designs, and anticipated technological advances [DeLauer, 1981].

Other examples of short range planning were cited in the ALCM program, where USAF told Boeing to avoid any provisions for growth that did not directly contribute to ALCM's current mission. Other service acquisition examples abound, and result in a very high cost for un-planned modifications. USAF was appropriated $1.6 billion dollars for FY 1980 for in-service aircraft modifications, almost half the cost of new aircraft acquisitions for that year (U.S. Congress, 1980b:1436). Short range planning not only degrades readiness but is very costly.

There is an implicit assumption in the DOD that provisions for long range growth in a system design will (1) degrade optimum system

performance, (2) be too costly, and (3) be wasted since the uncertain future will likely cancel many pre-planned improvements. As a result of these assumptions and the emphasis in short range planning, provisions for growth have been labeled "gold plating", thus taking a pejorative connotation and lessening the change that a contractor will win a contract award if he includes them in his proposal. The concepts of design to cost and life cycle cost reinforce this limitation. These concepts, as presently implemented, assume for analysis that a system will remain in its initial configuration; the uncertainty of future planning prohibits any analysis beyond the initial configuration. Thus, the cost of P^3I prerequisites are included in the life cycle cost analysis, but the reductions in improvement costs are not. As a result, prerequisites are seen only to increase system cost, and there is little chance for them to be included in a proposal.

The result of these restrictions is an acquisition system that has no experience in long range planning, or managing its inherent uncertainty. Perhaps this is why the Defense Secretary has directed DOD to begin P^3I programs; the short range strategy of the present acquisition system has become so ingrained in the minds of acquisition managers that they are unable to effectively plan beyond the short range.

Conclusion Nine: The potential pay-offs in P^3I for manufacturing tooling, processes, and facilities savings are great and should not be ignored.

Discussion: The thesis focused on the role of P^3I in product design. However, equally as important is the role of P^3I in manufacturing design. The thesis only briefly mentioned the role of P^3I in Boeing's production

plant, that P^3I could make changes in both volume and quality of products on the production line easier. Thus, the manufacturing facility itself can be pre-planned for growth by including prerequisites and design features that make changes easier. A manufacturing example was illustrated as a simple P^3I application earlier in this chapter.

Manufacturing P^3I applications have potential for improving the industrial base. Most people believe that industry needs to be completely modernized with the latest technology in production equipment. Interestingly enough, this is parallel to the current thinking behind highly complex weapon system requirements. As stated earlier, the thesis of P^3I is that the most advanced technology is not necessarily the best, unless it is designed for improvements. As an alternative to expensive modernization, industry could accept more basic equipment, but design their manufacturing facilities to accommodate additions of improved machinery in future years.

Recommendations

The thesis research objective was to "evaluate existing program examples that use P^3I as a strategy for long range system improvement and to develop policy and procedures for formal P^3I implementation by the services." The research findings indicate that industry endorses P^3I, and will take the initiative to pre-plan on their own, even in the face of DOD regulations that prohibit pre-planning. The findings also indicate that the services have very little experience with P^3I. Therefore, the most constructive policy or procedure is not to add new regulations to implement P^3I, but to relax current regulations to support, rather than inhibit, industry P^3I efforts.

Recommendation One: Link industry planning with DOD forecasts of threat, technology, and mission requirements.

Discussion: As noted in the research on managing improvement uncertainty, future forecasts are the basis for selecting and planning improvements. However the present DOD acquisition system focuses on the short range, which is perhaps the greatest single impediment to pre-planning. If the DOD is to support P^3I, intelligence agencies in the DOD as well as in other areas of the government must focus not only on the current threat, but on future forecasts. Since these forecasts are essential for planning, they must be made at least partially available to industry for planning and designing a new system, and also as a basis for developing new improvements. Similarly, the findings showed that the program manager was a key figure in directing the P^3I effort, thus he too must have these forecasts to effectively direct P^3I in his program.

Recommendation Two: Link government/industry labs with P^3I programs to develop planned improvements.

Discussion: The findings showed that technology uncertainty could be reduced as labs worked closely with design engineers to develop pre-planned improvements. Mr. Sullivan, DOD consultant for national security, noted that labs should be given "test beds", such as an aircraft, against which to develop pre-planned improvements. Mr. Sullivan stated, "The prize should go to the lab that develops a new technology that will fit (has been pre-planned) into an existing system, not a breakthrough in pure research that is of no immediate benefit [Sullivan, 1981]." Along with the effort of labs to develop improvements, goes the requirement for funding. Programs will continue to compete for limited funds, but

funds must be made available to develop and implement improvements if P^3I is to be successful. In essence, recognition that P^3I is a continuing effort leads to the conclusion that a system is in a continuous "improvement phase" after it is fielded, and that improvement phase must be supported by the acquisition system.

Recommendation Three: Expand life cycle cost evaluations to include the savings from reduced improvement costs.

Discussion: Currently, life cycle cost evaluations assume that total cost evaluations must be based upon an initial system configuration, simply because the direction of future improvements is too uncertain to estimate life cycle costs for anything but an initial configuration. Industry experience with P^3I has shown this assumption to be false. Improvement uncertainty is manageable, and if prerequisites are included in a system design, although they will increase system cost slightly, they will reduce real life cycle costs significantly. Thus, estimates of improvement costs should be included in life cycle cost equations, along with both the reward and cost of prerequisites.

To manage improvement uncertainty, a model similar to Figure 14, "Example of Prerequisite Flexibility" might be used with prerequisite weights. Prerequisite weight x (reward-cost) yields an expected value of improvement savings. This value could be used as a management tool to select prerequisites and also factored into life cycle cost evaluations. The details of such a model are beyond the scope of this thesis.

Recommendation Four: Educate acquisition managers to the P^3I process.

Discussion: The DOD is attempting to institutionalize the P^3I process with guidelines listed in the July 6, 1981 Carlucci Memo. It will be

a large step for service acquisition managers to move from short range to long range planning, since acquisition managers have little experience with it. Many P^3I implementation concerns were voiced at the ADPA P^3I Seminar & Workshop. One concern surfaced most often, not only in the P^3I literature, but in interviews with Dr. Lyon, Mr. Sullivan, and Mr. Steiner: the key to P^3I implementation lies not in institutionalizing P^3I, since acquisition managers are already over-burdened with squares to fill. Successful P^3I implementation first will require a change in the thought process of acquisition managers, followed with the support of the acquisition system in the P^3I effort. Thus, acquisition managers must become acquainted with P^3I, well beyond the guidelines that are presented in the Carlucci Memo. Certainly, working closely with industry in a P^3I effort will provide some of that education, but not every acquisition manager will have that opportunity. Thus, there is a need for an expanded policy statement to explain P^3I specifically to acquisition managers. This document is a logical follow-up effort to this thesis.

APPENDIX A

ABBREVIATIONS

ACIU	Advanced Central Interface Unit
ADPA	American Defense Preparedness Association
AFALD	Air Force Acquisition Logistics Division
AFIT	Air Force Institute of Technology
AFLC	Air Force Logistics Command
AFSC	Air Force Systems Command
ALCM	Air Launch Cruise Missile
AMRAAM	Advanced Medium Range Air-to-Air Missile
AQI	Directorate of Logistics Integration
ASD	Aeronautical Systems Division
ASIP	Aircraft Structural Integrity Program
ASPJ	Airborne Self Protection Jammer
AWC	Air War College
CAD/CAM	Computer Aided Design and Manufacturing
CIA	Central Intelligence Agency
DCS	Deputy Chief of Staff
DIA	Defense Intelligence Agency
DMT	Dual Mode Transmitter
DOD	Department of Defense
DTU	Data Transfer Unit
ECP	Engineering Change Proposal
ECS	Environmental Cooling System
ESD	Electronic Systems Division
EW	Electronic Warfare
FCC	Fire Control Computer
FY	Fiscal Year
GAO	Government Accounting Office
GPS	Global Positioning System
Hq	Headquarters
HUD	Heads Up Display
IG	Inspector General
JTIDS	Joint Tactical Information Display
LANTIRN	Low Altitude Navigation and Targeting Infrared Night
MAJCOM	Major Command
MFD	Multifunction Display
MMP	Master Modification Plan
MSIP	Multinational Staged Improvement Plan
NATO	North Atlantic Treaty Organization
NSA	National Security Agency
OMB	Office of Management and Budget
OSD	Office of the Secretary of Defense
P^3I	Pre-Planned Product Improvement
PSP	Programmable Signal Processor
RA	Radar Altimeter
R&D	Research and Development
RDT&E	Research Development Test and Evaluation
SPO	System Program Office
TAC	Tactical Air Command
UFCNI	Up Front Communications/Navigation/Identification
U.S.	United States
USAF	United States Air Force
USSR	Union of Soviet Socialist Republic

APPENDIX B

P^3I SUMMARY BRIEFING

Founded 1919

P^3I

PRE-PLANNED PRODUCT IMPROVEMENT

SUMMARY BRIEFING

AMERICAN DEFENSE PREPAREDNESS ASSOCIATION

DEDICATED TO PEACE WITH SECURITY THROUGH DEFENSE PREPAREDNESS

BACKGROUND

- OSD TASKING LETTER TO ADPA
- MEETING FORMAT
- MEETING PARTICIPANTS
- DSMC ASSISTANCE

MAJOR OBJECTIVES

- TOTAL SYSTEM COST REDUCTION
- POTENTIAL OF LONGER SYSTEM LIFETIME BEFORE REPLACEMENT NECESSARY
- INITIAL RISK REDUCTION
- SLOWER OBSOLESCENCE RATE
- HIGHER OPERATIONAL READINESS DURING LIFETIME
- SOLUTION TO AFFORDABILITY PROBLEM
- HIGHER AVERAGE PERFORMANCE DURING SYSTEM LIFETIME

GENERAL GUTHRIE

-- MATERIAL ALTERNATIVES TO NEW SYSTEMS MUST BE CONSIDERED

-- PRESENT SYSTEMS ARE GROWING OBSOLETE RAPIDLY

-- 400 (GROWING TO 800) PIPS ACTIVE PER YEAR DURING 78-82 PERIOD

-- 0.9-1.3 BILLION FUNDING REQUIREMENTS DURING 78-82 PERIOD

-- 6.6 YEARS TO COMPLETE A PIP

-- 80% OF PIPS FOR IMPROVED OPERATIONAL CAPABILITY, RELIABILITY & MAINTAINABILITY

-- NEED TO STRESS COST REDUCTION AS WELL

-- TIME IS AS IMPORTANT AS MONEY - BETTER IS THE ENEMY OF GOOD

-- COHERENT SCHEDULING OF EACH PROGRAM EVOLUTION MUST BE IMPLEMENTED

-- THE PRESENT POTPOURRI OF APPROACHES - CREATES DOUBTS IN CONGRESS ABOUT WHAT WE ARE DOING

-- WE NEED A BETTER BALANCE BETWEEN THE CONCEPT OF NEW SYSTEM AND CONCEPT OF UPGRADE

ADMIRAL WHITTLE

-- NAVY HAS EXPERIENCE, PARTICULARLY WITH SHIPS, ON PERIODIC INCREMENTAL IMPROVEMENTS

-- THE DD963 WAS THE FIRST CASE OF PRE-PLANNING - SPACE AND WEIGHT WERE RESERVED

-- THE EXPERIENCE TO DATE HIGHLIGHTS FOUR PROBLEMS:

- THE DEFINITION OF INTERFACE IS VERY COMPLEX
- THE INTERACTION OF PI ON PERIPHERAL SYSTEMS IS NOT OBVIOUS
- SYSTEM TEST BED TO MEASURE EFFECT OF SUBSYSTEM IMPROVEMENTS IS ESSENTIAL
- THE IN-HOUSE TECHNICAL CAPABILITY TO EVALUATE THE EFFECT OF CHANGE IS ESSENTIAL

-- A/C UPGRADES ARE NOW MORE FEASIBLE, PARTICULARLY THE USE OF SMART WEAPONS ON OLD AIRFRAMES

-- IN FUTURE, WE MUST PREPARE FOR PI; E.G. P^3I

-- WE CAN'T AFFORD TO PRODUCE ALL WE DESIGN

-- P^3I IS A REVOLUTIONARY APPROACH THAT IS NEEDED

GENERAL SLAY

-- PI IS A WAY OF LIFE FOR USAF

-- $4 BILLION PI'S ON B-52 PAST 26 YEARS - $6.5 BILLION PLANNED IN ADDITION

-- FY 81 BUDGET REQUESTS 1/2 AS MUCH FOR PI AS FOR NEW PROCUREMENT

-- F-16 AFTER 10 YEARS IN INVENTORY MAY WELL HAVE MORE CONFIGURATIONS THAN F-4 (19)

-- ACQUISITION IS AN EXTREMELY COMPLEX PLANNING TASK - YET IT IS IMPORTANT TO PROVIDE PROVISIONS FOR GROWTH THROUGH PLANNING

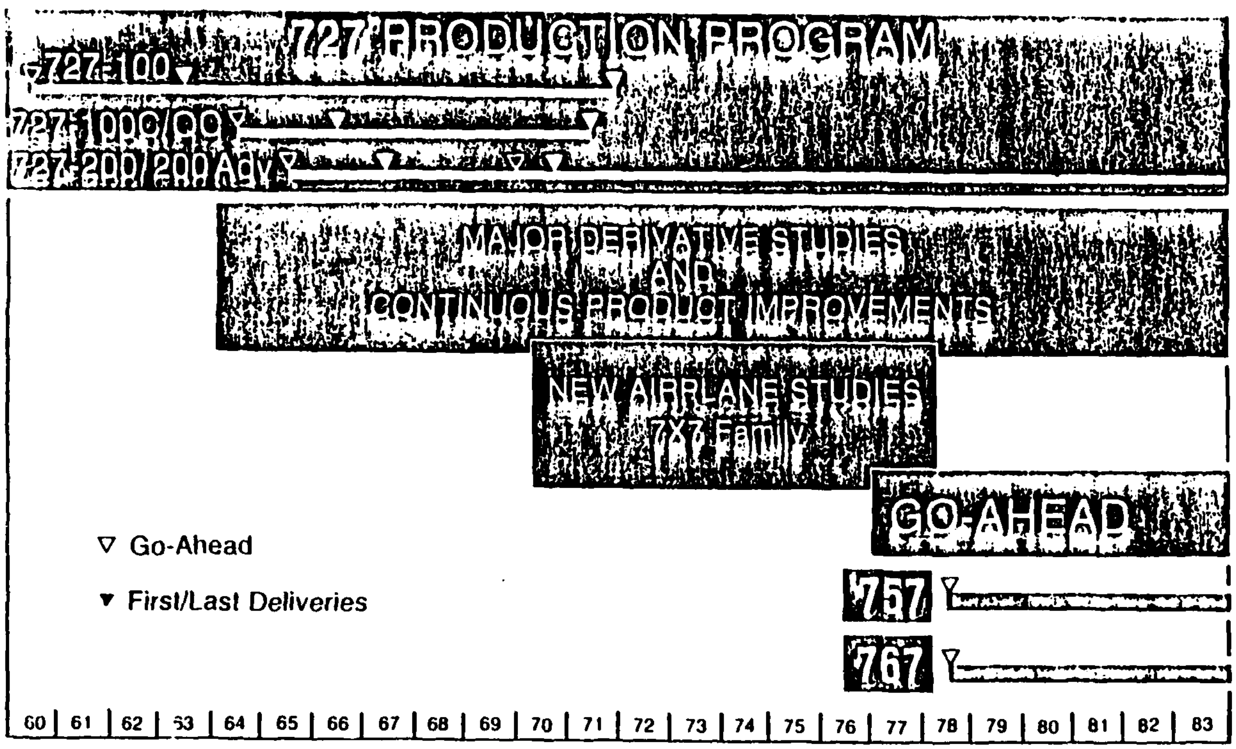
-- ALL MODS HAVE RECENTLY BEEN INCLUDED IN MAINSTREAM PLANNING

-- MODS WILL BE INCLUDED IN SYSTEM MASTER PLANS

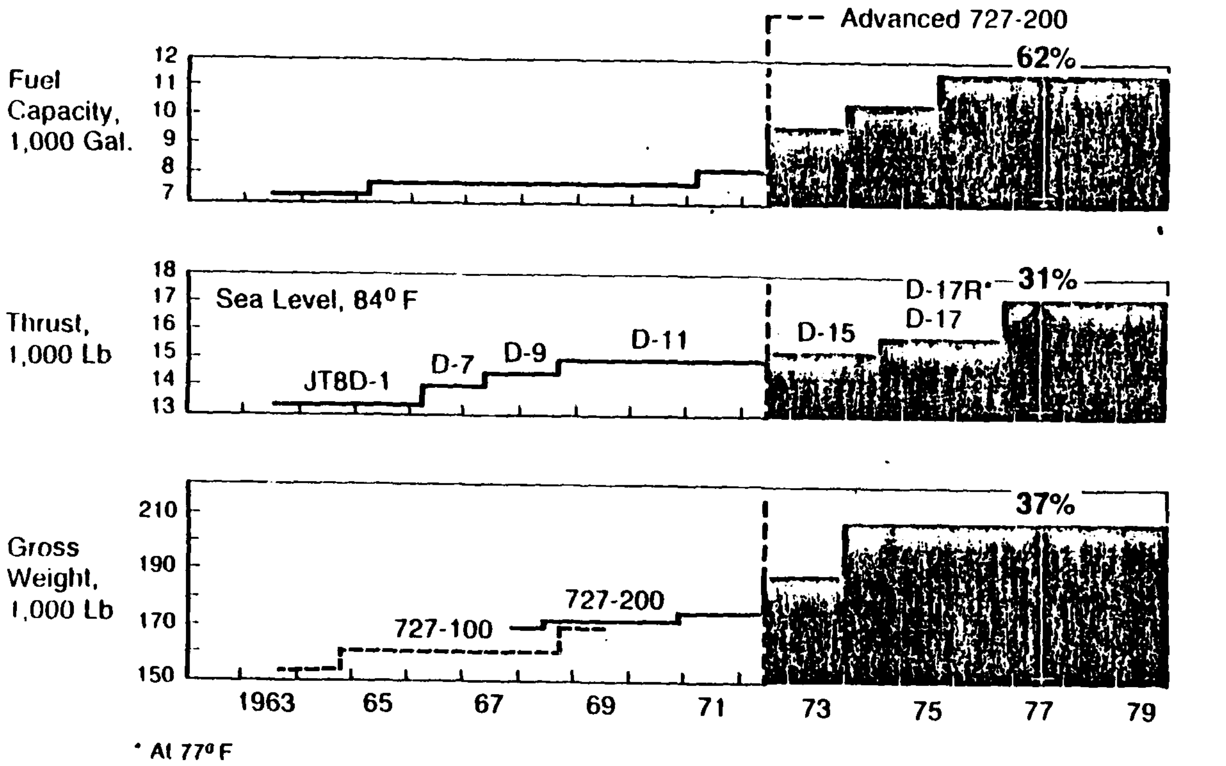
-- MANAGING THE PLACEMENT OF UPGRADES AND MULTI-YEAR COMMITMENTS ARE KEY FACTORS IN REDUCING COSTS

Product Improvements vs New Airplanes

Medium Range



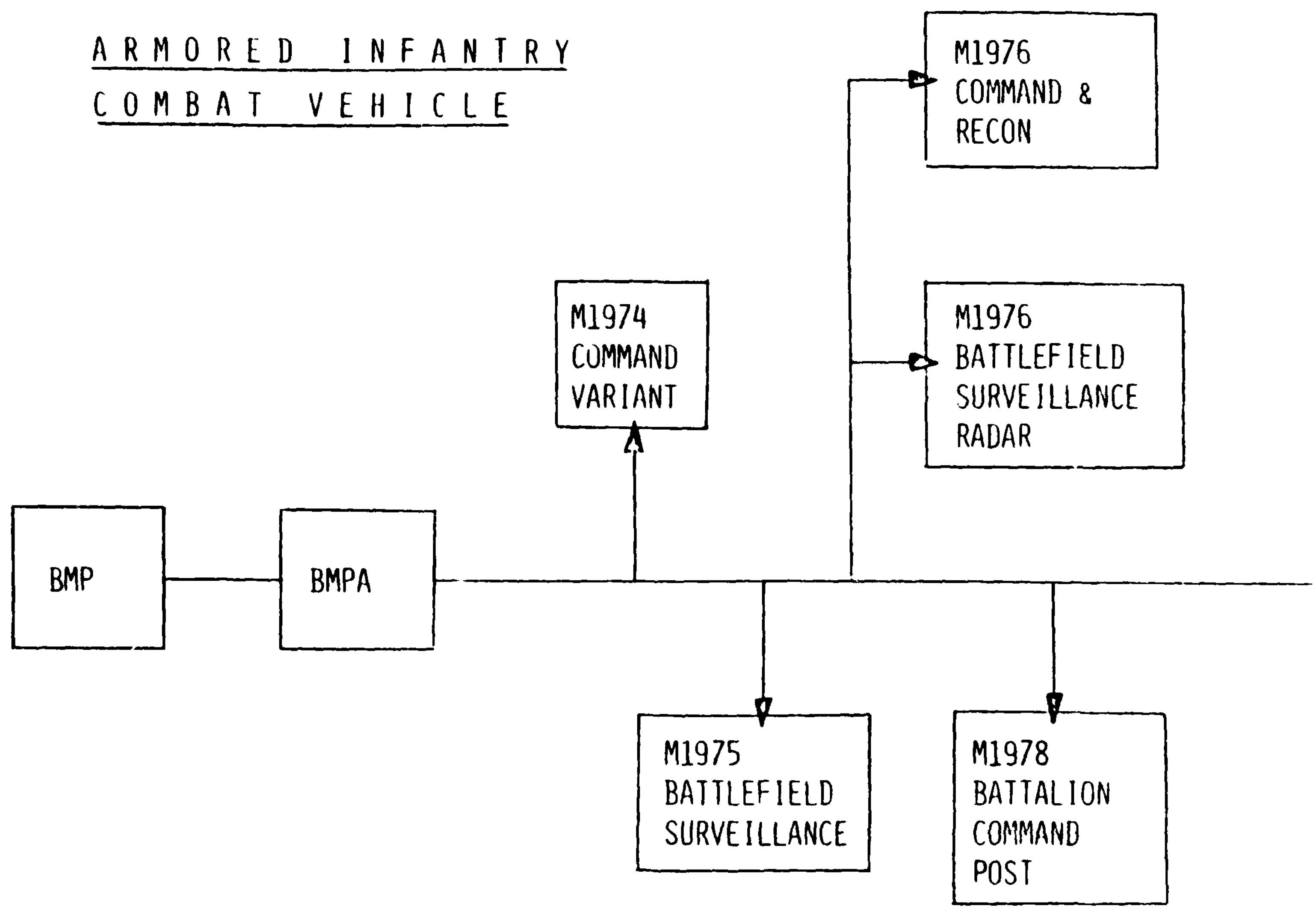
727 Development



SOVIET PRACTICE

- EVERY WEAPON DESIGN IS IMPROVED. NEW AND OLD ARE BLENDED WITH WEIGHT GIVEN TO PRODUCT IMPROVEMENT.
- LONG TERM STABILITY OF PURPOSE IN MANAGEMENT OF PROGRAMS.
- OPTIMIZING OVERALL FIELDED CAPABILITY, NOT THE PERFORMANCE OF A SINGLE SYSTEM.
- PERFORMANCE IMPROVED THROUGH NUMEROUS UPGRADING ACTIONS, AND EVOLUTIONARY DESIGN CHANGES.
- CONTROLLED RISK CONSIDERED IN CHOICE OF APPROACH.
- GROWTH POTENTIAL EXHAUSTED BEFORE NEW SYSTEM STARTED. NEW SYSTEM CONTAINS A SIGNIFICANT AMOUNT OF DESIGN INHERITANCE.
- ALSO FOCUS EFFORT ON INTENSIVE DEVELOPMENTS OF NEW WEAPONS CONCEPTS.

ARMORED INFANTRY COMBAT VEHICLE



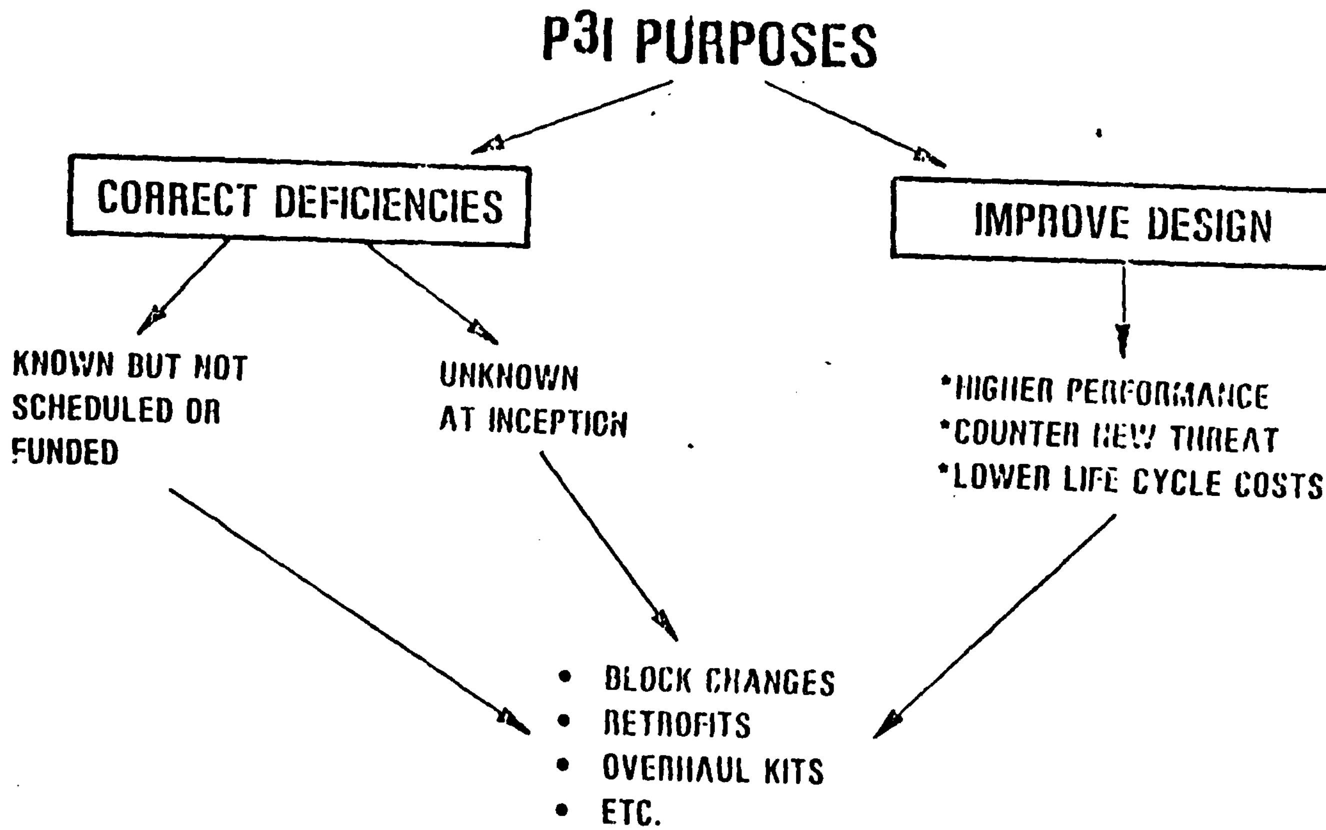
DEFINITION FOR P^3I

P^3I IS A SYSTEMATIC AND ORDERLY ACQUISITION STRATEGY BEGINNING AT THE SYSTEMS CONCEPT PHASE TO FACILITATE EVOLUTIONARY COST EFFECTIVE UPGRADING OF A SYSTEM THROUGHOUT THE LIFE CYCLE TO ENHANCE READINESS, AVAILABILITY AND CAPABILITY.

THE MODULAR BASELINE CONFIGURATION DESIGN SHALL PERMIT GROWTH TO MEET THE CHANGING THREAT AND/OR TO TAKE ADVANTAGE OF SIGNIFICANT TECHNOLOGICAL AND/OR OPERATIONAL OPPORTUNITIES THROUGH FUTURE MODIFICATIONS OR PRODUCT IMPROVEMENTS AT APPROPRIATE TIME INTERVALS.

THE BASELINE TECHNOLOGICAL RISK WILL BE MINIMIZED AND PROVIDE EARLY AVAILABILITY BY UTILIZING WELL KNOWN AND ESTABLISHED TECHNOLOGY TO THE MAXIMUM EXTENT FEASIBLE, LIMITING ADVANCED TECHNOLOGY TO THE SUBSYSTEM(S) OFFERING SUBSTANTIAL OPERATIONAL OR COST BENEFITS.

P3I DEFINITIONS



CRITERIA FOR P^3I

(COMPARED TO NEW START AND PI)

	P^3I	NEW START	PI
MOTIVATION FOR CHANGE	• PLANNED FOR EACH UPGRADE	• FORECAST LIFE OF ENTIRE SYSTEM	• IN REACTION TO EVENTS
PREPARATION FOR CHANGE	• R&D ON SELECTED COMPONENTS	• R&D ON ENTIRE SYSTEM	• SERENDIPITY -- TECHNOLOGY BASE BREAKTHROUGH, NEW THREAT OR DEFICIENCY
ORGANIZATION FOR CHANGE	• REPLACE MODULE	• REPLACE ENTIRE SYSTEM	• COMPLEX INTERFACES MUST BE RESOLVED
DESIGN LIFETIME	• DIFFERENT FOR EACH MODULE	• MAXIMUM FEASIBLE FOR ALL COMPONENTS	• WHATEVER IS AVAILABLE AT TIME OF PI
PERFORMANCE RELATIVE TO SOA THRU SYSTEM LIFE	• ON AVERAGE, CLOSEST AVAILABLE SOA	• HIGH AT START, ERODES AFTER DESIGN FREEZE	• CATCH-UP MODE -- FARTHEST FROM SOA
PROCUREMENT PLAN	• FOR DEFINED MODULES	• FOR ENTIRE SYSTEM	• AS NEEDED
CONFIDENCE IN MEETING COST & SCHEDULE	• HIGH DUE TO MANAGEABLE # OF CHANGES	• POOR YIELD DUE TO LARGE # OF SUBSYSTEM CHANGES	• IS OFTEN IN RESPONSE TO PREVIOUS FAILURE TO MEET GOALS
CONFIDENCE IN THREAT PREDICTION	• HIGHER DUE TO SHORTER TIME FRAME	• POOR BECAUSE OF LONG RANGE OF PROJECTION	• IN REACTION TO THREAT CHANGES
BUDGETING APPROACH	• FUNDING WEDGE PROVIDED AT EARLY TIME	• SPECIFIC ACTIONS FUNDED IN ADVANCE	• NO ADVANCE FUNDING PROVISIONS

PROGRAM MANAGEMENT OBJECTIVES OF P^3I

START

(1)	REDUCE TECHNOLOGICAL RISK	-- INITIAL REQUIREMENTS CAN BE WRITTEN FOR SHORTER TIME HORIZON THAN A NEW START
(2)	INSURE CAPACITY FOR GROWTH	-- SYSTEM PERFORMANCE GROWTH THROUGH PLANNED UPGRADES MUST BE A BASIC PART OF INITIAL EVALUATION
(3)	SYSTEM ARCHITECTURE DESIGNED TO ACCOMMODATE GROWTH	-- UPGRADES PLANNED BY PROGRAM MANAGER INTERFACE CONTROL A KEY MANAGEMENT THRUST
(4)	SUBSYSTEM (MODULE) CHARACTERISTICS DESIGNED TO DIFFERENT TIME HORIZON THAN MAIN FRAME	-- SUBCONTRACTORS WILL RECOMPETE SUBSYSTEMS WHERE APPROPRIATE

PROGRAM MANAGEMENT OBJECTIVES OF P^3I

DURING PROGRAM LIFE

(1) PROGRAM MANAGER MAINTAINS P^3I PLAN

(2) R&D FUNDS PROGRAMMED IN TIMELY FASHION TO DEFINE UPGRADE PACKAGES

(3) SUBCONTRACTORS COMPETE TO UPDATE SYSTEMS SELECTED FOR UPGRADING

(4) PROGRAM MANAGER UPDATE SYSTEM LEVEL DESIGN FEATURES

REQUIRES

-- MODULAR SYSTEMS

-- RESERVE CAPACITY

-- INTERFACE CONTROL

C O N C L U S I O N S

- APPROACH APPEARS APPLICABLE ACROSS WEAPON SPECTRUM
- INDUSTRY WILL SUPPORT IF CAN COMPETE PROFITABLY AND MAKE CONTRIBUTION
- WON'T WORK WITHOUT CONGRESS AND OSD SUPPORT
- BASIC PROBLEM IS CULTURAL PREFERENCE FOR NEW STARTS, LATEST TECHNOLOGY -- EVEN WHEN PREMATURE
- LOGISTIC COMMUNITY CAN SUPPORT P^3I
- MAY PROVIDE EARLIER DEPLOYMENT OF SUPPORTABLE SYSTEM
- COULD INCREASE EMPHASIS ON LIFE CYCLE COSTS
- COULD HELP FOCUS 6.2 & 6.3, PROVIDING TECHNOLOGY "PULL"
- PRESENTLY MAKE CHANGES; SELDOM PLAN AHEAD FOR THEM
- CHANGING 5000.1 WILL NOT GUARANTEE DESIRED EFFECTS AND COULD BE COUNTERPRODUCTIVE

MAJOR CONCERNS

- P^3I COMPETES WITH MORE GLAMOROUS NEW STARTS
- CURRENT CONGRESSIONAL ATTITUDES ARE NOT CONDUCIVE
- CONCURRENT R&D & PROCUREMENT MAY DRAW QUESTIONS
- ANTICIPATED LATER P^3I MAY NEVER MATERIALIZE
- GROWTH PROVISIONS MAY BE LABELLED "GOLD-PLATING"
- GROWTH PROVISIONS MUST BE "MANDATORY" NOT "DESIRABLE" TO PROTECT COMPETITIVE POSITION OF PARTICIPANTS
- FUNDING UNCERTAINTIES INTRODUCE RISK
- THERE IS NO INCENTIVE PRESENTLY TO REDUCE FUTURE PI COSTS THROUGH P^3I
- COULD GENERATE NEW BUREAUCRATIC WICKETS, BUZZ-WORDS, GROUPS

LESSER CONCERNS

- UNCERTAINTY OVER REACHING FUTURE PERFORMANCE LEVELS
- MAY INCREASE MULTIPLE CONFIGURATIONS IN THE FIELD
- OVERDEPENDENCE ON WILLINGNESS TO COMPETE IN NEW ENVIRONMENT
- LACK OF MANAGEMENT CONTINUITY CAN CRIPPLE APPROACH
- COULD CREATE ADDITIONAL MANAGEMENT PROBLEMS WITH NATO ALLIES

RECOMMENDATIONS

(1) RAISE P^3I INTEREST ON PAR WITH NEW STARTS

(2) MAKE P^3I OPPORTUNITY MANDATORY IN RFP'S AND CONTRACTS

(3) ASSURE ADEQUATE P^3I FUNDING IN ALL PROGRAMS

(4) SELECT A FEW HIGH EMPHASIS PROGRAMS TO INITIATE P^3I

(5) MODIFY PROCESS TO REFLECT TIME PHASED REQUIREMENTS

R E C O M M E N D A T I O N S

(1) RAISE P^3I INTEREST ON PAR WITH NEW STARTS

- CONSIDER P^3I IN MISSION AREA ANALYSES
- FORMULATE P^3I IN SERVICE ACQUISITION DOCUMENTS
- WRITE REQUIREMENTS DOCUMENTS TO OPTIMIZE POTENTIAL OF P^3I
- CONSIDER MULTIPLE APPROACH IN RFP'S, P^3I, AND NEW DESIGNS
- USE EXISTING BUDGET LINE STRUCTURE TO FUND P^3I
- DON'T CLAIM NEW POLICY OR ATTRACT NEW CULT
- DON'T TRY TO DRAFT RIGID P^3I CRITERIA
- CLARIFY CURRENT VAGUENESS OF 5000.1/5000.2

RECOMMENDATIONS (CONTINUED)

(2) MAKE P^3I OPPORTUNITY MANDATORY IN RFP'S AND CONTRACTS

- "DE-RATE" TECHNOLOGY APPLICATIONS THAT INCREASE RISK UNNECESSARILY
- ATTRACT R&D FUNDS TO P^3I BY:
  - -- INCREASING SUBSYSTEM COMPETITION
  - -- INCENTIVES FOR IR&D APPLIED TO P^3I
  - -- ENCOURAGE UNSOLICITED PROPOSALS
  - -- INTERNATIONAL PARTICIPATION IN BLOCK UPGRADES
- INSIST ON NEW SYSTEM MODULARITY
- ESTABLISH INTERFACES & DATA/DOCUMENTATION REQUIREMENTS TO ENHANCE P^3I
- ASSURE NEW SYSTEM GROWTH PROVISIONS
- ESTABLISH PRODUCTION RATES TO OPTIMUM P^3I RATES

RECOMMENDATIONS (CONTINUED)

(3) ASSURE ADEQUATE P^3I FUNDING IN ALL PROGRAMS

- P^3I SHOULD BE PART OF PROGRAM PLAN BY MILESTONE II
- DISCIPLINE ED PHASE: EARLY FREEZE + BLOCK CHANGES LATER
- P.M. MUST SHARE VISIBLE & FUNDED P^3I PLAN WITH:
  - -- INDUSTRY (PRIMES & SUBCONTRACTORS)
  - -- LABORATORIES
- P.M. MAY NEED P^3I PROTOTYPE TESTBEDS IN PROGRAM
- RECOGNIZE P^3I FOR R/M IS FUNDAMENTAL PROGRAM COST
- REQUIRE GOOD OPERATIONAL DATA FEEDBACK TO P.M. FOR P^3I

RECOMMENDATIONS (CONTINUED)

(4) SELECT A FEW HIGH EMPHASIS PROGRAMS TO INITIATE P^3I

- NEW PROGRAMS:
  - -- F-18, TOMAHAWK, PATRIOT, ROLAND, CRUISE MISSILE, F-16 LANTIRN
- MATURE PROGRAMS:
  - -- F-14, FFG-7, UH-60, IMPROVED HAWK, F-15, E-3A, P-3
- EXPAND EFFORT IF THESE APPEAR SUCCESSFUL

(5) MODIFY PROCESS TO REFLECT TIME PHASED REQUIREMENTS

- TIME PHASE REQUIREMENTS IN RELATION TO BLOCK UPGRADE SCHEDULE
- FEED P^3I OPPORTUNITIES INTO REQUIREMENTS PROCESS

APPENDIX C

CARLUCCI MEMORANDUM

AP - Action

THE DEPUTY SECRETARY OF DEFENSE

WASHINGTON D C 20301

JUL 6 1981

MEMORANDUM FOR SECRETARIES OF THE MILITARY DEPARTMENTS
CHAIRMAN, JOINT CHIEFS OF STAFF
UNDER SECRETARIES OF DEFENSE
ASSISTANT SECRETARIES OF DEFENSE
GENERAL COUNSEL
ASSISTANTS TO THE SECRETARY OF DEFENSE

SUBJECT: Improving the Acquisition Process Through Pre-Planned Product Improvements

In my memorandum of 30 April, I directed an evolutionary and lower technological risk concept of Pre-Planned Product Improvement (P^3I) be implemented as a means of reducing unit costs and decreasing acquisition time. An implementation plan has been developed in cooperation with the Services and is attached hereto.

The Military Departments are requested to take the following actions as specified in the plan:

1. Within the next 90 days, examine ongoing and recently fielded major programs for potential P^3I applications, estimate the benefits, and present appropriate programmatic recommendations at the next milestone decision point. Call special program reviews in off-milestone years when needed. Necessary funding should be identified in the PPBS cycle. Non-major programs should be reviewed at the next Service review point or not later than the FY 84-88 POM submittal in a similar fashion.

2. Include consideration of P^3I in the acquisition strategy established for all new programs.

3. Appoint organizational focal points for P^3I and so notify OUSDRE within 30 days. These organizational elements should be charged with overall P^3I responsibilities and chartered to review individual programs before and after fielding for application of P^3I strategy and planning.

Frank C. Carlucci

Attachment
as stated

48567

AP 144-1

PRE-PLANNED PRODUCT IMPROVEMENT (P^3I)
IMPLEMENTATION PLAN

DEFINITION

P^3I is an acquisition concept which programs resources to accomplish the orderly and cost effective phased growth or evolution of a system's capability, utility, and operational readiness.

OBJECTIVES

The objectives of P^3I are to:

- shorten the acquisition and deployment time for a new system or an incremental capability;

- reduce overall acquisition and operating and support costs;

- extend useful life of equipment;

- combat military obsolescence;

- reduce technical, cost, and schedule risk;

- accomplish orderly growth from initial to mature system reliability; and

- reduce logistics and support problems entailed with new materiel introduction.

APPLICATIONS

P^3I is ideally applied to a new system at program initiation when it can be a factor in concept selection and validation. P^3I is subsequently carried forward in the development by including growth potential in the basic design to accommodate future evolutionary improvements and by making the architecture (or structure) of the system sufficiently flexible to accomodate modular changes.

For ongoing systems, i.e., those already in FSD or beyond, P^3I may be limited by the original design parameters to subsystem changes and other modifications that can be incorporated without experiencing prohibitively high redesign, production incorporation, and retrofit costs or excessive equipment downtime.

APPLICATION CRITERIA

P^3I is viewed as a useful acquisition concept under the following circumstances. For new programs:

- there is a long term military requirement to be satisfied;

- the threat or need is projected to change as a function of time requiring a change in the response;

- required technical performance or system capability is expected to increase with time;

- there is a need to field the system in the near term with less than its full capability; and

- the sponsoring service is willing to pay the higher initial costs to obtain growth potential for future exploitation.

Additionally, for ongoing programs:

- there is a change in the threat requiring increased capability or utility which is technically feasible to obtain;

- there has been a technological breakthrough in advanced development which presents the opportunity for significant advancement in system military worth;

- improvement in design provides a cost effective means of meeting otherwise unattainable readiness requirements;

- the system is modular or adaptive to accept upgrading;

- sufficient capacity for growth has been demonstrated in the design in the form of structural, space, weight, and power provisions to incorporate the needed engineering changes without prohibitive modification costs in production or retrofit; and

- the system service life is compatible with the changes entailed.

POLICY CHANGES

The following changes to the provisions of DoDD 5000.1, Major System Acquisitions and DoDI 5000.2, Major System Acquisition Procedures, will be staffed for incorporation in the next revision to these documents.

DoDD 5000.1, insert a new paragraph, D.2.g, Pre-Planned Product Improvement (renumbering subsequent subparagraphs accordingly). "The concept of Pre-Planned Product Improvement (P^3I), the orderly, time phased introduction of incremental system capability to accommodate projected changes in threat or to reduce risk in initial fielding of the system, will be employed as an integral part of the program acquisition strategy. P^3I modifications will adhere to the same system acquisition policy, procedures, budget, and milestone decision principles and constraints as the basic system. P^3I efforts should correspond to clearly defined performance levels, readiness and sustainability levels or changes in the military threat. P^3I should be pursued when it is clearly established that its application will reduce risk, acquisition time, and/or overall cost and will not be used to artificially extend the development effort or correct deficiencies encountered in attaining initially specified system performance."

DoDI 5000.2, paragraph D.4.a, Acquisition Strategy - Revise the third sentence to read, "Acquisition strategy encompasses the entire acquisition process for the basic system as well as any Pre-Planned Product Improvements."

DoDI 5000.2 - Add a new subparagraph 8.1. - Pre-Planned Product Improvement. "The basic design of the system will anticipate any Pre-Planned Product Improvements (P^3I) which are identified in the military requirement documents and subsequently contained in the acquisition strategy and confirmed at milestone decisions. Provisions will include structure, space, weight, moment, power, air conditioning, and other accommodations to facilitate production incorporation and retrofit and minimize operational disruptions."

DoDI 5000.2, enclosure 2, Mission Element Need Statement (MENS) Format. Add a last sentence to paragraph B, Threat or Basis for Need. "When an evolutionary development or Pre-Planned Product Improvement concept is considered appropriate to meet stepped requirements or anticipated changes in threat or because of technological risk, the priority to be afforded system growth potential will be specified."

DoDI 5000.2, enclosure 3, Decision Coordinating Paper (DCP Format) - Revise Part IV to read:

"Part IV: Summarize system and program alternatives including Pre-Planned Product Improvements considered and the reasons why the preferred alternative was selected."

DoDI 5000.2, enclosure 4, Integrated Program Summary (IPS) Format - Change paragraph 2, Program Alternatives, to read:

"In addition to the program proposed by the DoD component in the DCP, briefly describe each DCP alternative program and Pre-Planned Product Improvement including its advantages and disadvantages."

GUIDANCE

The Services are to approach P^3I as a design change mechanism for the phased introduction of incremental system capabilities at specifically defined points in time. Each evolutionary materiel change should fully meet a corresponding aspect of the threat or exploit a technological advantage.

P^3I is not to be used for correction of deficiencies encountered in the basic development. In particular, P^3I is not a test and fix technique to achieve reliability, availability, and maintainability (RAM) specified for initial operation; however, P^3I is an appropriate means to achieve planned growth from initial to mature RAM levels. Resources to accomplish P^3I will be made visible during the PPBS cycle and placed in the FYDP (POM/BES) and EPA. Once P^3I becomes a part of the acquisition strategy, failure to fund it will be considered a major change in program direction.

P^3I is to be used where there are legitimate technical and schedule risk impediments to proceeding with a full capability system and not as a ruse to initiate an underfunded and unaffordable program. The latter case programs are destined to become deficient in performance or suffer early cancellation.

P^3I provisions in the design should be recognized in the application of Design to Cost, Value Engineering, or other cost control/savings techniques.

DIRECTION

The Services will make P^3I an integral part of the material acquisition process and incorporate its provisions in new and ongoing programs to the extent feasible and appropriate.

- The materiel requirement document should include the concept of stepped requirements and sequential performance and readiness increases and list growth potential as a high priority characteristic.

- P^3I should be placed in the program acquisition strategy and detailed in the system program management document schedules and resource computations.

- Growth requirements should be translated into design criteria and substantiated through development test.

- Achievement of growth provisions may be incentivized, as appropriate, in the development contract.

- P^3I modifications should be scheduled, programmed, budgeted, and planned for force introduction with the same attention to detail as the basic system.

Within 90 days, the Services will review each major system for P^3I opportunities in the form of large pay-off's for incremental design changes or conversely problem subsystems where less technological sophistication can reduce time, cost, and/or improve RAM characteristics without prohibitive loss in capability. Non-major programs will be reviewed at the next service review point or not later than the FY 84-88 POM submittal. A list of candidate systems for application of P^3I will be defined by each Service. Programs on this list will be documented in preparation for the next milestone or special program review by inclusion of P^3I in the acquisition strategy and program alternatives. Where such course of action becomes the Service recommended alternative, necessary funding will be proposed during the PPBS cycle.

Within 30 days, the Services will appoint P^3I organizational focal points for administering P^3I policy guidance. The focal points will be chartered with overall P^3I responsibilities and tasked with reviewing P^3I provisions on individual programs when presented for subsequent milestone and program review decisions and with reviewing opportunities for further P^3I after deployment.

SELECTED BIBLIOGRAPHY

A. REFERENCES CITED

Aguilano, Nicholas J., and Richard B. Chase. Production and Operations Management. Illinois: Richard D. Irwin, Inc., 1977.

ASD/YP. "F-16 Weapon System Master Modification Plan (U)." The F-16 System Program Office, Wright-Patterson AFB, Ohio, June 1980.

ASD/YPDT. "F-16 MSIP Test and Evaluation Master Plan." The F-16 System Program Office, Wright-Patterson AFB, Ohio, February 1981.

ASD/YPPP. "The F-16 MSIP Program Management Plan." The F-16 System Program Office, Wright-Patterson AFB, Ohio, 1981.

Air Force Systems Command. A Guide For Program Management, AFSCP 800-3. Andrews AFB, DC, 9 April 1976.

Air Force Systems Command. "Meeting on Modification Management, 17 August 1979." Unpublished minutes, Andrews AFB, DC, 21 August 1979.

American Defense Preparedness Association. P^3I Seminar & Workshop and Proceedings. Unpublished research report, unnumbered, Arlington, VA: ADPA Headquarters, 1980.

American Defense Preparedness Association. "P^3I Summary Briefing." Unpublished briefing guide, unnumbered, Arlington, VA: ADPA Headquarters, 1981.

ARINC Research Corporation. "Aircraft Modification Management Evaluation." Air Force Business Research Management Center, Contract F33615-80-C-5102, Wright-Patterson AFB, Ohio, December 1980.

Ashley, Holt, Professor of Aeronautical Engineering, Stanford University. "On Making Things The Best - Aeronautical Uses of Optimization," Paper No. AIAA 81-1738. Wright-Patterson AFB, Ohio, August 11, 1981.

Augustine, Norman R. "P^3I: An Idea Whose Time Has Come ... Again." National Defense LXV, No. 364 (January 1981), pp 27-31,62.

Baldwin, Truxtun R. Under Secretary of Defense for Research and Engineering. Washington, DC. Telephone interview. 25 June 1981.

Balven, Captain Terry L., USAF. "Acquisition of Class V Modifications," AQI Project Report, Projects 77-23 through 77-27. AFALD/AQI, Wright-Patterson AFB, Ohio, 16 February 1979.

Bernstein, Thomas N., Aerospace Engineer. Structures Division, Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio. Telephone interview. 21 August 1981.

Blackledge, Lt Col Ronald G., USAF, Assistant Professor of Acquisition Management. Air Force Institute of Technology, Wright-Patterson AFB, Ohio. Personal interviews conducted 15 June 1980 through 3 September 1981.

The Boeing Company. "An Overview of The Boeing Company," Unpublished summary report. The Boeing Company, Seattle, Washington, April 1981.

Bowes, C. M. "Aerodynamic Development of the 727-100," Case Study in Aircraft Design, The Boeing 727. American Institute of Aeronautics and Astronautics, Professional Study Series. September 14, 1978.

Campbell, Howard, Chief Functional Engineer, ALCM. Wright-Patterson AFB, Ohio. Telephone interview. August 5, 1981.

Carlucci, Frank C., Deputy Secretary of Defense. "Improving the Acquisition Process," Memorandum For Secretaries of The Military Departments. Washington, DC: Government Printing Office, April 30, 1981. (a)

Carlucci, Frank C., Deputy Secretary of Defense. "Improving the Acquisition Process Through Pre-Planned Product Improvements," Memorandum For Secretaries of The Military Department. Washington, DC: Government Printing Office, July 6, 1981. (b)

Currie, Dr. Malcolm R., Director of Defense Research and Engineering. The Department of Defense Program of Research, Development, Test and Evaluation, FY 1978, Statement to the 95th Congress. Washington, DC: Government Printing Office, 18 January 1977.

Defense Science Board. Report of the Acquisition Cycle Task Force, 1977 Summer Study. Washington, DC: Government Printing Office, March 1978.

Defense Science Board. Reducing The Unit Cost of Equipment, 1979 Summer Study. Washington, DC: Government Printing Office, March 1980.

Defense Science Board. Panel on Industrial Responsiveness, 1980 Summer Study. Washington, DC: Government Printing Office, January 1981.

DeLauer, Dr. Richard D., Under Secretary of Defense for Research and Development. "Electronic Warfare Acquisition," Memorandum For Service Secretaries For R&D. Washington, DC: Government Printing Office, June 19, 1981.

Department of Defense. Major System Acquisitions, DODD 5000.1. Washington DC: Government Printing Office, March 19, 1980.

Government Accounting Office. Impediments to Reducing The Costs of Weapon Systems. Washington, DC: Government Printing Office, November 8, 1979.

General Accounting Office. Improved Management of Air Force Modification Programs Can Save Millions, Report to the Secretary of Defense. Washington, DC: Government Printing Office, March 16, 1981.

General Dynamics. Engineering Change Proposal 0350, Early Provisions For Improved Capability. General Dynamics, Fort Worth, Texas. November 1980.

Gifford, Charles A., Technical Advisor. Systems Engineering Avionics Facilities Branch. Wright-Patterson AFB, Ohio. Personal interview. 12 June 1981.

Gilbertson, R. ARINC Research Corporation, Dayton, Ohio. Telephone interview. 10 March 1981.

Gregoire, M. C. "The 727-200 Development," Case Study in Aircraft Design, The Boeing 727. American Institute of Aeronautics and Astronautics Professional Study Series. September 14, 1978.

Gregory, William H. "Mods and Pods." Aviation Week and Space Technology, Vol. 113, No. 20 (November 17, 1980), p. 11.

Gregory, William H. "Streamlining the Acquisition Process." Aviation Week and Space Technology, Vol. 114, No. 18 (May 4, 1981), p. 9.

"The Growth Industry's Growth Industry." Forbes, Vol. 128, No. 1 (July 6, 1981 , pp 144,146.

Hanbrich, Capt William, USAF, Test and Evaluation Manager. Electronic Counter Measures, ALCM, Wright-Patterson AFB, Ohio. Telephone interview. 16 August 1981.

Klein, Barbara J., GS-12, and Michael A. Smigel, GS-12. "An Acquisition Alternative: System Modification To Satisfy Mission Needs." Unpublished masters thesis. LSSR 16-79B, AFIT/LS, Wright-Patterson AFB, Ohio, September 1979. ADA 076923.

Lavoie, Colonel Robert P., USAF. "A Faster Response to Threat Changes and User Requirements." Unpublished research paper, Report No. 392, Air War College, Maxwell AFB AL, April 1978. ADB 029123L.

Lyon, Dr. Hylan B. "Pre-Planned Product Improvement." National Defense, LXV, No. 364 (January 1981), pp 20-25. (a)

Lyon, Dr. Hylan B., ADPA P^3I Committee Chairman, Corporate Manager of Government Liason. Texas Instruments, Arlington, Virginia. Personal and telephone interviews conducted April 10, 1981 through August 21, 1981. (b)

MacIsaac, Captain Richard S., USAF. "A Guide for the AFLC Program Manager of Major Production Class IV & V Modifications." Unpublished masters thesis, LSSR 30-79B. AFIT/LS, Wright-Patterson AFB, Ohio, August 1979. ADA 077673.

"Modular Evolutionary Development Proposed." National Defense, LXIV, No. 358 (February 1980), p. 52.

Montle, Louise K., Development Study Manager. The Boeing Company, Seattle, Washington. Personal and telephone interviews conducted 24 July 1981 to 21 August 1981.

Morris, Major William W., USAF, F-16 Multinational Staged Improvement Program Manager. Wright-Patterson AFB, Ohio. Personal and telephone interviews conducted 23 April 1981 to 19 August 1981.

Office of Management and Budget. The Budget of the United States Government, FY 1981. Washington, DC: Government Printing Office, 1981.

OO-ALC/MMS. F/RF-4 Modification Management Plan. Hill Air Force Base, Utah, July 1980.

Osborne, D. A., F-16 Financial Manager. Wright-Patterson AFB, Ohio. Personal interview. 16 February 1981.

Pratt, Lt Col Robert, Headquarters, Aeronautical Systems Division. "Individual Report," Commercial Practices Program, Boeing Airplane Company. Unpublished research report. Washington: Headquarters Air Force Systems Command, January 1981. (a)

Pratt, Lt Col Robert J., USAF. Headquarters, Aeronautical Systems Division, Wright-Patterson AFB, Ohio. Personal and telephone interviews conducted 15 January 1981 to 21 August 1981. (b)

Perry, Dr. William J., Under Secretary of Defense Research and Engineering. The FY 1982 Department of Defense Program For Research, Development, and Acquisition, Statement to the 97th Congress. Washington, DC: Government Printing Office, 20 January 1981.

Puritano, Vincent, The Executive Assistant to the Deputy Secretary of Defense. "Improving the Defense Acquisition System and Reducing System Costs," Department of Defense Steering Group Report. Washington, DC: Government Printing Office, March 31, 1981.

Ralston, Anthony, (Ed.). Encyclopedia of Computer Science. New York: Van Nostrand Reinhold Company, 1976.

SA-ALC/MMS. Master Plan for C-5A Galaxy. Kelly AFB, Texas, 1980.

Schemmer, Benjamin F. "Ripples and Waves in the National Security Tidal Basen," Armed Forces Journal. Vol. 118, No. 12 (August 1981), pp 59-64.

Steiner, John E. "Requirements and Major Decision Outline: Total Program," Case Study in Aircraft Design, The Boeing 727. American Institute of Aeronautics and Astronautics Professional Study Series, September 14, 1978.

Steiner, John E. "Jet Aviation Development: One Company's Perspective, The Last Forty Years and a Brief Look at the Future." National Air and Space Museum, Smithsonian Institute, 1979.

Steiner, John E. "Commercial Transport Aircraft Trends: Present and Future." Center for Advanced Engineering Study, Massachusetts Institute of Technology, October 10, 1980.

Steiner, John E. "The Economies of Technological Advancements, An Aircraft Manufacturer's Perspective." International Civil Aviation Conference Number Three, Paris, France, June 3, 1981. (a)

Steiner, John E., Vice President, Corporate Product Development. The Boeing Company, Seattle, Washington. Personal interview. 24 July 1981. (b)

Sullivan, Leonard, Assistant Secretary of Defense, Program Analysis and Evaluation (1973-1976). Washington, DC. Telephone interview. 30 June 1981.

Terrell, James H., Jr., Special Assistant to the Deputy Under Secretary of Defense for Research and Advanced Technology. Washington, DC. Telephone interview. 7 August 1981.

United States Air Force. Modification Program Approval, AFR 57-4 (C1). Washington, DC: Government Printing Office, 1 September 1978.

United States Congress, House of Representatives Subcommittee on the Department of Defense. Department of Defense Appropriations for 1981. Hearings Part 3, 96th Congress, 2d Session, 1980. Washington, DC: Government Printing Office, 1980. (a)

United States Congress, Senate Subcommittee on the Department of Defense. Department of Defense Appropriations for 1981, Hearings Part 5, 96th Congress, 2d Session, 1980. Washington DC: Government Printing Office, 1980. (b)

"USAF to Fund F-16XL Development, Plus F-15E." Armed Forces Journal. Vol. 118, No. 12 (August 1981), p. 16.

Utterstrom, J. R., Vice President and General Manager of the Boeing ALCM Program. The Boeing Company, Seattle, Washington. Personal interview. 24 July 1981.

Weinberg, Victor. Structured Analysis. New York: Yourdon Press, 1979.

B. RELATED SOURCES

Aeronautical Systems Division. Multiplex Applications Handbook, MIL-STD-1553. Wright-Patterson AFB, Ohio, 6 April 1981.

AFALD/PTEEE. Styleguide For Preparation of Modification Plans (Draft). Wright-Patterson AFB, Ohio, 1981.

Department of Defense. Major System Acquisition Procedures. DODI 5000.2. Washington DC: Government Printing Office, March 19, 1980.

Grosson, Joseph F. "P^3I Competition, Standardization and Systems Engineering." National Defense LXV, No. 364 (January 1981), pp 25-26.

Office of Management and Budget. Major System Acquisitions, CMB Circular No. A-109. Washington DC: Government Printing Office, April 5, 1976.

"Pre-Planned Improvement, Design-To-Cost Conflict Possible, Says GAO." Aerospace Daily, May 21, 1981, p. 118.

"P^3I Requirements Should Be Written Into RFPs For New Systems, GAO Says." Aerospace Daily, August 19, 1981, p. 274.

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